SOLAR RADIATION UV-INDEX CHARACTERIZATION AND SKIN CANCER IMPLICATIONS FOR EXPOSED INDIVIDUALS IN BENIN CITY

BY

EKEBERE CHETACHUKWU EVANS

PSC2105489

DEPARTMENT OF PHYSICS

FACULTY OF PHYSICAL SCIENCES

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BENIN CITY.

NOVEMBER, 2025

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A PROJECT SUBMITTED TO THE DEPARTMENT OF PHYSICS, FACULTY OF PHYSICAL SCIENCES,

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR SCIENCE (B.Sc.) OF THE UNIVERSITY OF BENIN, EDO STATE, NIGERIA

NOVEMBER, 2025

CERTIFICATION

This is to certify that this research work was carried out and presented by **MR EKEBERE CHETACHUKWU EVANS**, with matriculation number

PSC2105489, of the Department of Physics, Faculty of Physical Sciences, University of Benin, Benin City, Edo State, Nigeria.

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MR. J. A. ABIOLA **Date**

(Project Supervisor)

______________________ ______________________

PROF. C. O. AIGBOGUN **Date**

(Head of Department)

______________________ ______________________

External Examiner **Date**

DEDICATION

This work is dedicated to God Almighty, my biggest source of help throughout my academic career.

ACKNOWLEDGEMENT

I want to thank parents Mr. and Mrs. Kingsley Ekebere, my siblings for their emotional support throughout my journey through the university and the time I was working on my project

Also, thanks to MR. J. A. ABIOLA my project supervisor, whose advice, expertise clarifications, tolerance, and encouragement were invaluable in helping me finish this study.

Special Shout out to my SUCF Brethren for all the love and support

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ABSTRACT

This study examined solar radiation and ultraviolet (UV) index characterisation in Benin City, Nigeria, with a specific focus on the potential implications for skin cancer among exposed individuals. The research aimed to assess the intensity, variation, and temporal distribution of solar and UV radiation across different months and seasons using secondary data obtained from the Copernicus Atmospheric Monitoring Service (CAMS)**.** The analysis provided insights into the patterns of solar radiation exposure within the city, identifying periods of high UV intensity that coincide with greater risks of skin damage and related health effects.

A comprehensive literature review explored the concept of solar radiation and the UV index, the global patterns of UV radiation exposure, and the biological effects (both beneficial and harmful) of ultraviolet radiation. The study highlighted the types of skin cancers commonly associated with UV exposure, including basal cell carcinoma, squamous cell carcinoma, and melanoma. Empirical evidence from previous research reinforced the link between high UV radiation and increased incidence of skin cancer, particularly in tropical and high-altitude regions.

Results from the CAMS data analysis revealed that Benin City experiences significant fluctuations in solar and UV radiation throughout the year, with peak values recorded during the dry season when cloud cover is minimal. These findings underscore the need for increased public awareness, protective measures, and policy interventions aimed at reducing the health risks associated with excessive solar exposure. The study concludes that continuous monitoring of solar radiation and UV index levels is essential for effective environmental health management. Recommendations include implementing UV index forecasts, promoting protective infrastructure, encouraging sunscreen use, and strengthening occupational health policies for outdoor workers.

Overall, the research contributes valuable data and practical insights to the understanding of solar radiation dynamics and their public health implications in tropical urban environments like Benin City.

CHAPTER ONE

1.0 INTRODUCTION

Solar radiation is the stream of electromagnetic energy emitted by the Sun that sustains life and drives all atmospheric and climatic processes on Earth. It encompasses a wide spectrum of wavelengths, including ultraviolet (UV), visible, and infrared radiation. As this radiation passes through the atmosphere, a portion is absorbed, scattered, or reflected by gases, clouds, and surface materials, while the remainder reaches the ground as the energy that supports photosynthesis, weather formation, and heat balance.

To monitor and communicate the potential risk of UV exposure, the Ultraviolet Index (UVI) was developed as an international standard measure. The UVI quantifies the intensity of sunburn-producing ultraviolet radiation at a particular place and time. Its values typically range from 0 (Low) to 11+ (Extreme), depending on factors such as solar angle, ozone concentration, altitude, and cloud cover. In tropical regions like Nigeria, where sunlight is intense throughout most of the year, UVI values often remain high, making awareness and protection essential for preventing radiation-related health effects.

1.1 BACKGROUND OF THE STUDY

Solar radiation is the primary source of energy that sustains life on Earth and drives the planet's climatic and atmospheric processes. It consists of electromagnetic waves that range from ultraviolet (UV) through visible to infrared radiation. When solar radiation reaches the Earth's atmosphere, it undergoes absorption, reflection, and scattering by gases, aerosols, and clouds, influencing the amount of energy that ultimately reaches the surface (NASA Earth Observatory, 2022). The fraction that penetrates to ground level forms the global solar radiation, which comprises both direct and diffuse components. This energy not only regulates temperature and weather patterns but also supports photosynthesis, solar energy production, and various biological and environmental systems (Seinfeld & Pandis, 2016).

Among the components of solar radiation, ultraviolet (UV) radiation has attracted particular scientific and health attention. UV radiation is divided into three bands—UVA (315–400 nm), UVB (280–315 nm), and UVC (100–280 nm)—based on wavelength. While UVC is completely absorbed by the stratospheric ozone and does not reach the surface, UVA and UVB penetrate the atmosphere to varying extents. UVB, in particular, is biologically active, capable of inducing chemical and physiological changes in living organisms. It plays a beneficial role in human health through the synthesis of vitamin D but can also be harmful in excessive doses, contributing to skin ageing, DNA damage, and skin cancer (World Health Organization [WHO], 2023).

To monitor the intensity and potential biological effects of UV radiation, the **Ultraviolet**

Index (UVI) was developed by the World Health Organization, the World Meteorological Organization, and the United Nations Environment Programme. The UVI quantifies the strength of sunburn-producing UV radiation at a particular time and location on a scale from 0 (low risk) to 11+ (extreme risk). It provides a practical means of communicating health risks associated with UV exposure and serves as a global public health tool (UNEP, 2021). Variations in the UVI are influenced by several factors including solar elevation, ozone concentration, altitude, surface reflectivity, and cloud cover.

Globally, UV radiation exposure is unevenly distributed. The highest intensities occur in tropical and subtropical regions, particularly near the equator, where solar angles are more direct and atmospheric filtering is minimal. This makes equatorial areas, such **as** Benin City, Nigeria, significant in studies on solar radiation and health implications. Benin City is located in the southern region of Nigeria, roughly between latitude 6.34°N and longitude 5.62°E**.** The city experiences **a** tropical climate, characterised by high humidity, intense solar radiation, and a bimodal rainfall pattern. Average daily temperatures range from 24°C to 34°C, and the area receives substantial solar insolation throughout the year. These climatic and geographical features make it particularly suitable for investigating UV radiation patterns and their potential effects on human health (NIMET, 2023).

Over recent decades, growing concerns have emerged regarding the increasing incidence of UV-related health problems, particularly skin cancer. The depletion of the ozone layer, coupled with changes in lifestyle and occupational exposure, has intensified public health interest in understanding the relationship between solar radiation, UV intensity, and human vulnerability. Studies across different regions have shown that prolonged exposure to UV radiation without adequate protection can result in severe biological effects, including photoageing, immunosuppression, cataracts, and carcinogenesis (Narayanan, Saladi, & Fox, 2010; Lucas et al., 2019). Understanding the patterns and intensity of solar radiation, especially the UV component, in specific regions such as Benin City is therefore crucial for developing localised public health interventions and preventive strategies.

1.2 PROBLEM OF THE STUDY

In tropical environments like Benin City, individuals are continuously exposed to high levels of solar radiation due to geographical positioning and climatic conditions. Outdoor workers, including artisans, traders, and transport operators, are particularly vulnerable to prolonged UV exposure. Despite the recognised health implications, there is limited localised research quantifying UV radiation intensity and its correlation with skin cancer risk in Nigeria. Most existing studies on solar radiation focus on photovoltaic energy applications, with minimal attention to the biomedical implications of UV exposure on human health.

Furthermore, while global studies have established a link between UV intensity and the prevalence of skin cancers such as basal cell carcinoma, squamous cell carcinoma, and melanoma, there is insufficient empirical data from sub-Saharan African cities to support local preventive health policies. This gap in data limits the ability of environmental health authorities to implement evidence-based public awareness programmes. Additionally, the public's understanding of the Ultraviolet Index (UVI) remains low, leading to poor protective behaviour during high-exposure periods. Therefore, a comprehensive characterisation of solar radiation and UV index in Benin City, and its implication for skin cancer among exposed individuals, is necessary to bridge this research gap.

1.3 RESEARCH AIM AND OBJECTIVES

The primary aim of this study is to characterise solar radiation and UV index patterns in Benin City and evaluate their implications for skin cancer risk among exposed individuals**.**

To achieve this aim, the study will pursue the following objectives:

1. To quantify solar radiation and ultraviolet index values for Benin City using Copernicus Atmospheric Monitoring Service (CAMS) radiation data.
2. To analyse temporal variations in solar and UV radiation across different months and seasons.
3. To examine the relationship between UV intensity and potential skin cancer risks based on WHO exposure guidelines.
4. To identify population groups most vulnerable to UV-related health risks, particularly outdoor workers.
5. To propose preventive and mitigation strategies for reducing UV-induced health effects within the study area.

1.4 SIGNIFICANCE OF THE STUDY

This research is significant in several respects. Scientifically, it contributes to the growing body of knowledge on solar radiation characterisation in equatorial regions and provides valuable insight into local UV index behaviour in Benin City. It also helps establish a baseline for continuous environmental health monitoring and can inform predictive modelling of UV exposure trends under changing climatic conditions.

From a public health perspective, the study highlights the link between environmental radiation and dermatological health, which can guide preventive measures and awareness campaigns. By correlating radiation data with potential skin cancer risk levels, this research provides evidence that can support the development of health education programmes, particularly for high-risk groups such as outdoor workers and individuals with lighter skin pigmentation or pre-existing medical conditions.

Furthermore, the study has policy relevance, offering practical recommendations for government agencies such as the Nigerian Meteorological Agency (NiMet), the Federal Ministry of Health, and local environmental protection bodies. It may also contribute to urban planning by informing the need for shaded public spaces and UV safety advisories. Lastly, the findings will serve as a reference for future academic research on the interaction between solar radiation, climate, and public health in tropical cities.

CHAPTER TWO: LITERATURE REVIEW

2.1 CONCEPT OF SOLAR RADIATION AND THE UV INDEX

Solar radiation refers to the electromagnetic energy emitted by the Sun, encompassing a wide spectrum of wavelengths ranging from ultraviolet (UV) to visible and infrared (IR) radiation. This radiation forms the fundamental source of energy for the Earth, regulating climate, supporting photosynthesis, and sustaining life (NASA Earth Observatory, 2022). When solar radiation enters the Earth's atmosphere, part of it is absorbed by gases such as ozone, carbon dioxide, and water vapour, while another portion is reflected by clouds, aerosols, and bright surfaces like snow or sand. The remainder reaches the Earth's surface as **global solar radiation**, consisting of direct and diffuse components (Seinfeld & Pandis, 2016).

The **ultraviolet (UV)** portion of solar radiation is of particular importance because of its strong biological effects. Although it constitutes less than 5% of total solar energy, UV radiation has high photon energy capable of inducing photochemical reactions in living organisms (World Health Organization [WHO], 2023). UV radiation is classified into three bands:

- **UVA (315–400 nm)**: the least energetic, penetrates deep into the skin, and causes photoageing.
- **UVB (280–315 nm)**: more energetic and responsible for sunburn and DNA damage.
- **UVC (100–280 nm)**: completely absorbed by atmospheric ozone and oxygen, therefore does not reach the surface.

To communicate the potential biological risks of UV radiation, the Ultraviolet Index (UVI) was developed by the WHO, the World Meteorological Organization (WMO), and the United Nations Environment Programme (UNEP). It provides a standardised scale (0 to 11+) describing the intensity of erythema-causing UV radiation at the surface (UNEP, 2021). The UVI helps the public assess daily exposure risks and adopt protective measures. High UVI values indicate a greater likelihood of skin and eye damage, necessitating sun-protection strategies such as sunscreen use, protective clothing, and avoiding prolonged outdoor activity.

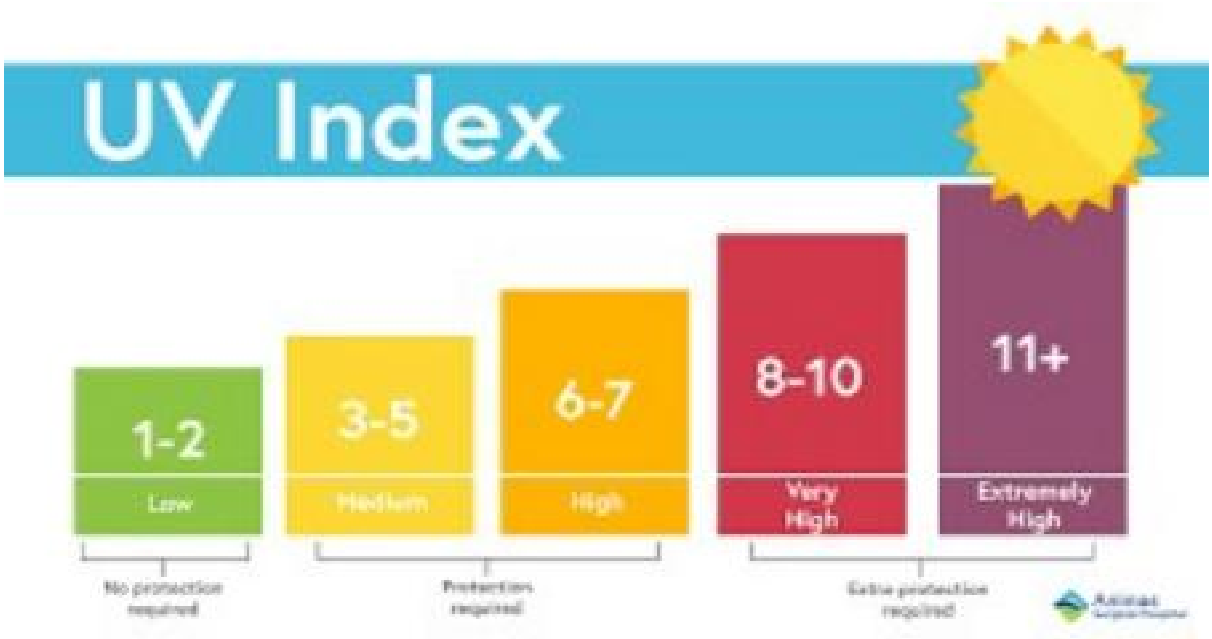

Fig 2.1: UV Index Graph

2.2 GLOBAL PATTERNS OF UV RADIATION EXPOSURE

The distribution of UV radiation across the globe is influenced by a combination of astronomical, atmospheric, and geographical factors. Latitude plays the most significant role; regions near the equator receive the highest UV intensities because the Sun's rays strike more directly, reducing atmospheric scattering. In contrast, polar regions experience lower UV exposure due to the oblique angle of solar incidence (Lucas et al., 2019).

Altitude also affects UV radiation levels. At higher elevations, the thinner atmosphere provides less filtering, leading to an approximate 10–12% increase in UV intensity for every 1,000 metres gained in elevation (Blumthaler, Gröbner, & Mayer, 2017). Ozone concentration further modulates exposure, areas with lower ozone levels, such as those affected by the Antarctic ozone hole, experience significantly elevated UV-B radiation.

Cloud cover and surface reflectivity modify the local UV dose received. Thick cloud layers tend to reduce UV intensity, while thin or scattered clouds may enhance it by reflecting radiation between the surface and atmosphere. Similarly, reflective surfaces such as snow, sand, and water increase exposure by bouncing UV rays upward, often doubling the effective dose received by individuals in such environments (Diffey, 2018).

Seasonal and diurnal variations also contribute to global patterns. UV radiation is typically highest during summer and midday hours, when solar elevation angles are greatest and lowest during winter and early morning or late afternoon (McKenzie et al., 2020). Consequently, tropical regions such as Benin City experience consistently high UV radiation throughout the year, whereas mid-latitude and Polar Regions show pronounced seasonal differences.

2.3 HEALTH EFFECTS OF ULTRAVIOLET RADIATION

Ultraviolet radiation has both beneficial and harmful biological effects depending on the wavelength, duration, and intensity of exposure.

Beneficial Effects

One of the most significant benefits of UV exposure is its role in vitamin D synthesis. When UVB radiation interacts with the skin, it converts 7-dehydrocholesterol into previtamin D_3, which is subsequently transformed into vitamin D_3 (cholecalciferol). This process is vital for calcium and phosphate metabolism, bone development, and immune regulation (Holick, 2017). Adequate vitamin D prevents disorders such as rickets, osteoporosis, and muscle weakness.

Controlled UV exposure is also applied in phototherapy, particularly for treating skin conditions like psoriasis, eczema, vitiligo, and dermatitis (Parisi, Downs, & Turner, 2018). Moreover, exposure to natural light supports circadian rhythm regulation and enhances psychological well-being by stimulating serotonin production, thereby improving sleep and mood (Figueiro & Rea, 2010).

Harmful Effects

Despite its benefits, excessive exposure to UV radiation can cause a range of health problems. UVA penetrates deep into the dermis, breaking down collagen and elastin fibres, leading to photoageing characterised by wrinkles and loss of skin elasticity (Fisher et al., 2016). **UVB** causes direct DNA damage, producing photochemical lesions such as cyclobutane pyrimidine dimers that, if unrepaired, lead to mutations and cancerous cell growth (Brash, 2015).

Cumulative UV exposure is the principal environmental cause of skin cancer, particularly basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma (Narayanan, Saladi, & Fox, 2010). Overexposure also contributes to **eye damage**, including cataracts and macular degeneration (Cullen, 2011), and can suppress immune responses, making individuals more vulnerable to infections and diseases (Norval et al., 2011).

2.4 TYPES OF SKIN CANCER ASSOCIATED WITH UV EXPOSURE

Prolonged exposure to UV radiation is strongly associated with the development of skin cancers, classified into three major types, basal cell carcinoma, squamous cell carcinoma, and melanoma.

Basal Cell Carcinoma (BCC) originates from the basal cells of the epidermis and is the most common but least aggressive form. Chronic exposure to UVB is the main cause. BCC often appears as a pearly nodule or ulcerated lesion, typically occurring on the face and neck (Lomas, Leonardi-Bee, & Bath-Hextall, 2012).

Squamous Cell Carcinoma (SCC) arises from keratinocytes and accounts for about 20–25% of skin cancer cases. It is more aggressive than BCC and can metastasise if untreated. SCC is linked to cumulative UV exposure and frequently appears on sun-exposed areas such as ears, lips, and forearms (Kauvar et al., 2021).

Melanoma, though less common, is the most lethal form of skin cancer, originating from melanocytes, the pigment-producing cells. It is primarily associated with intermittent, intense UV exposure, particularly during childhood. Melanoma can rapidly spread to internal organs if not detected early (Whiteman, Green, & Olsen, 2016).

Type of Skin Cancer	**Origin Cell**	**UV Association**	**Aggressiveness**	**Common Locations**
Basal Cell Carcinoma	Basal cells	Chronic UVB exposure	Low	Face, neck, shoulders
Squamous Cell Carcinoma	Keratinocytes	Cumulative UV exposure	Moderate	Ears, lips, hands
Melanoma	Melanocytes	Intermittent, intense UV exposure	High	Anywhere on body

2.5 EPIDEMIOLOGY OF SKIN CANCER IN HIGH UV REGIONS

Skin cancer is one of the most common forms of cancer globally, with incidence rates strongly correlated with ambient UV radiation levels. The World Health Organization (2023) estimates approximately 2–3 million non-melanoma and 132,000 melanoma cases annually worldwide. The highest prevalence occurs in regions such as Australia, New Zealand, and South Africa, where fair-skinned populations live under intense sunlight (Arnold et al., 2018).

In Africa, skin cancer remains a major health challenge, particularly among people with albinism and outdoor workers. Studies in Tanzania, Kenya, and Nigeria have identified squamous cell carcinoma as the most common type among individuals with albinism (Kiprono, Chaula, & Beltraminelli, 2014). Environmental factors such as ozone depletion, high solar elevation, and outdoor lifestyles contribute significantly to these trends.

Epidemiological patterns show that latitude, altitude, and behavioural factors such as sunbathing and occupational exposure determine regional variation. Although awareness campaigns have improved sun-protection behaviour in developed regions, developing countries still experience increasing incidence due to inadequate protective practices (Lucas et al., 2019).

2.6 FACTORS INFLUENCING VARIATION IN UV RADIATION

The amount of UV radiation that reaches the Earth's surface is influenced by several geographical, climatic, seasonal, and human factors. Geographically, proximity to the equator results in higher UV intensity because the Sun's rays are more direct. Similarly, higher altitudes experience stronger radiation due to thinner atmospheric layers (Blumthaler et al., 2017).

Climatic factors such as **cloud** cover, aerosol concentration, and ozone thickness alter radiation levels. Cloudy or polluted skies absorb UV rays, while ozone depletion enhances surface radiation (Bernhard et al., 2013). Reflective surfaces—snow, sand, and water—can amplify exposure by up to 80% (Diffey, 2018).

Seasonal variations arise from the Earth's tilt; UV levels are highest during summer when the Sun's path is more vertical, and lowest in winter. Diurnally, intensity peaks between 10 a.m. and 2 p.m. (Seckmeyer, Mayer, & Erb, 2015).

Human exposure patterns also play a vital role. Outdoor workers such as farmers, builders, and traders face prolonged exposure, often exceeding recommended safety limits (Modenese & Korpinen, 2020). Conversely, office workers face intermittent but intense exposure during recreational activities (Downs, Parisi, & Schouten, 2019).

2.7 PREVENTIVE AND PROTECTIVE MEASURES AGAINST UV RADIATION

Effective prevention of UV-related health risks requires both behavioural and institutional interventions. Individuals are advised to limit outdoor activities during peak sunlight hours, seek shade, and wear protective clothing such as hats, sunglasses, and long-sleeved garments (Narayanan et al., 2019). Sunscreen use remains essential, particularly broad-spectrum formulations with SPF 30 or higher, reapplied every two hours (Lucas et al., 2019).

At a societal level, public education programmes, such as Australia's "Slip! Slop! Slap!" campaign, have proven effective in reducing sunburn incidence (Whiteman et al., 2016). Technological tools like daily UV index forecasts enable informed decisions regarding outdoor exposure (WHO, 2023).

Policy-wise, workplace safety regulations should mandate protective gear for outdoor occupations, while urban planning should incorporate shaded structures and green spaces to reduce cumulative UV exposure (Modenese & Korpinen, 2020). On a global scale, environmental protection measures such as the Montreal Protocol, which regulates ozonedepleting substances, continue to safeguard the planet from excessive UV radiation (McKenzie et al., 2020).

2.8 REVIEW OF RELATED EMPIRICAL STUDIES

Empirical studies globally have explored patterns of solar radiation and UV exposure. Norval et al. (2014) reported that variations in UV radiation are influenced by latitude, altitude, ozone concentration, and cloud cover, with equatorial regions showing the highest values. Wright, Norval, and Reeder (2012) observed high rates of skin disorders in sub-Saharan Africa due to occupational exposure and limited protection.

In South America, Porfirio, dos Santos, and da Silva (2012) found significant UV fluctuations under different sky conditions, while Lucas, McMichael, Smith, and Armstrong (2018) estimated that over 60,000 deaths annually worldwide are linked to UV-induced skin cancers.

Locally, Okoro, Ehioghae, and Osahon (2020) assessed UV intensity in Benin City using ground data and found that daily UV indices often exceeded safe exposure limits. The authors emphasised occupational exposure among traders and artisans as a key risk factor, aligning with WHO's (2017) findings on tropical UV exposure risks. These studies collectively highlight the dual role of UV radiation—essential for vitamin D synthesis but dangerous when excessive—and the urgent need for regional awareness and policy interventions.

CHAPTER THREE: METHODOLOGY

The Copernicus Atmospheric Monitoring Service (CAMS) is a programme operated by the European Centre for Medium-Range Weather Forecasts (ECMWF)**.** It provides high-quality, near-real-time global data on the atmosphere, air quality, solar radiation, and climate indicators**.**

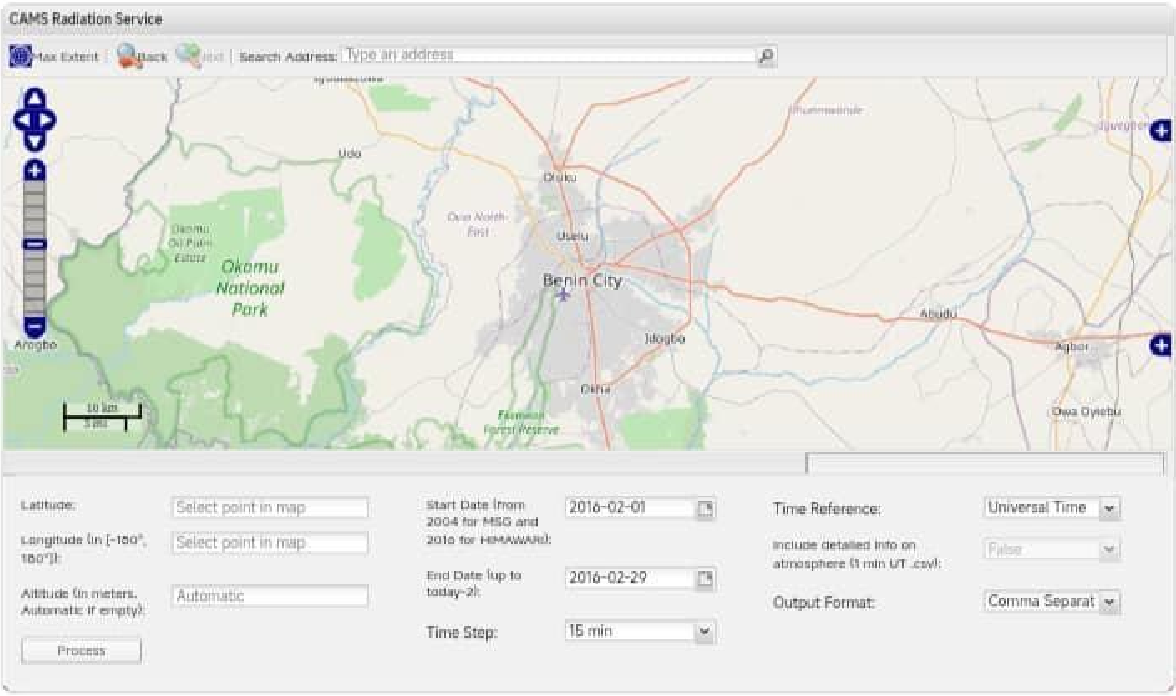

Fig 3.1: CAMS Radiation Data Site

The CAMS Radiation Service specifically delivers detailed datasets on solar radiation components**,** using satellite observations combined with advanced numerical weather prediction models. These datasets are widely used in environmental research, solar energy assessment, and climate studies**.**

The main parameters provided by CAMS include:

- **Global Horizontal Irradiance (GHI):** Total solar energy received on a horizontal surface, including both direct and diffuse sunlight.
- **Direct Normal Irradiance (DNI):** Solar energy received per unit area by a surface that is always held perpendicular to the Sun's rays.
- **Diffuse Horizontal Irradiance (DHI):** Solar radiation scattered by the atmosphere and clouds, reaching the surface indirectly.

- **Ultraviolet Index (UVI):** A measure of the strength of sunburn-producing ultraviolet radiation at the Earth's surface.

CAMS data are derived from satellite instruments such as Meteosat**,** MODIS, and Sentinel series sensors, processed with radiative transfer models that account **for** aerosols, ozone concentration, water vapour, and cloud coverage. The data are available at high spatial (up to 5–10 km) and temporal (hourly or daily) resolutions.

Erythemal radiation is given as [W/m²] x 40 m²/W = UV Index. The radiation was in wh/m2. So for monthly data, I calculated the total number of hours in the month and use it to divide the radiation data that will take it to w/m2. Then finally multiplied by 0.04 to convert to UV index The Formula below was used (Reinhold Rosemann, 2025)

$$UV\ Index = \frac{DHI}{hours\ per\ month} * 0.04$$

For this study, "Solar Radiation UV-Index Characterisation and Skin Cancer Implications for Exposed Individuals in Benin City" the CAMS radiation data were used to:

1. **Quantify Solar Energy Levels:**
   Daily and monthly averages of GHI, DNI, and DHI were obtained to determine how much solar radiation Benin City receives throughout the year.
2. **Analyse Seasonal Variations:**
   The data were grouped into **dry and wet seasons** to identify patterns of radiation fluctuation due to climatic changes such as cloud cover and humidity.
3. **Evaluate Ultraviolet Radiation Intensity:**
   The UV Index (UVI) data were extracted from CAMS to assess the strength of ultraviolet exposure and classify the potential health risks using WHO's risk scale (Low to Extreme)**.**
4. **Identify High-Risk Periods:**
   Graphical trends from the CAMS data helped pinpoint months with extreme UV values (above 10) , typically in the dry season , which correspond to the highest risk of skin damage and cancer.
5. **Support Public Health Assessment:**
   The radiation data provided empirical evidence for understanding how environmental factors (cloud cover, ozone, aerosols) influence UV levels and how these patterns translate into health implications for residents.

CAMS radiation data serve as a scientifically validated, globally consistent source for measuring and analysing solar and UV radiation. In this project, they enabled a quantitative evaluation of UV exposure in Benin City**,** providing the foundation for linking environmental data to public health outcomes, particularly the risk of skin cancer due to prolonged sun exposure.

CHAPTER FOUR

Data for the monthly variation in solar radiation within Benin city, Edo state Nigeria has been presented in Tables 1 – 10. These data cover a 10-year period of measurement of the solar radiation under clear sky conditions. The solar radiation was then analysed and converted to UV index parameter for the entire period under consideration. Also, the graphs showing the yearly variation in the UV index data are presented in Fig. 1 – 10

Table 1: Monthly Time - series of Solar Radiation for 2015

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	85310.02	4.59
Feb	74941.50	4.46
Mar	97356.38	5.23
Apr	94381.27	5.07
May	74388.34	4.00
Jun	69215.14	3.72
Jul	64403.37	3.46
Aug	65248.79	3.51
Sept	58123.36	3.12
Oct	61633.16	3.31
Nov	65785.21	3.54
Dec	82600.13	4.44

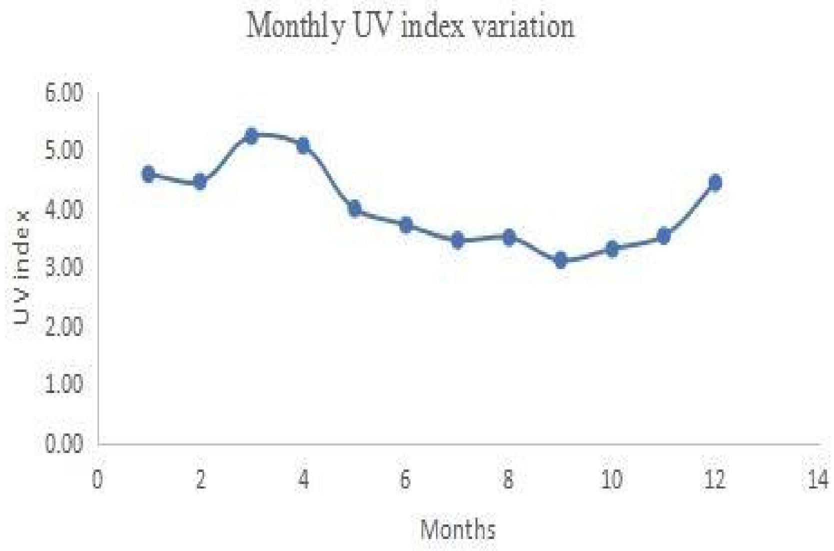

Fig. 4.1: Variation of monthly UV index for 2015

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Table 2: Monthly Time series of Solar Radiation for 2016

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	86491.89	4.65
Feb	92471.60	5.31
Mar	92016.08	4.95
Apr	78039.78	4.20
May	70739.89	3.80
Jun	66771.20	3.59
Jul	63578.22	3.42
Aug	67331.42	3.62
Sept	56614.88	3.04
Oct	66439.01	3.57
Nov	68876.41	3.70
Dec	74345.54	4.00

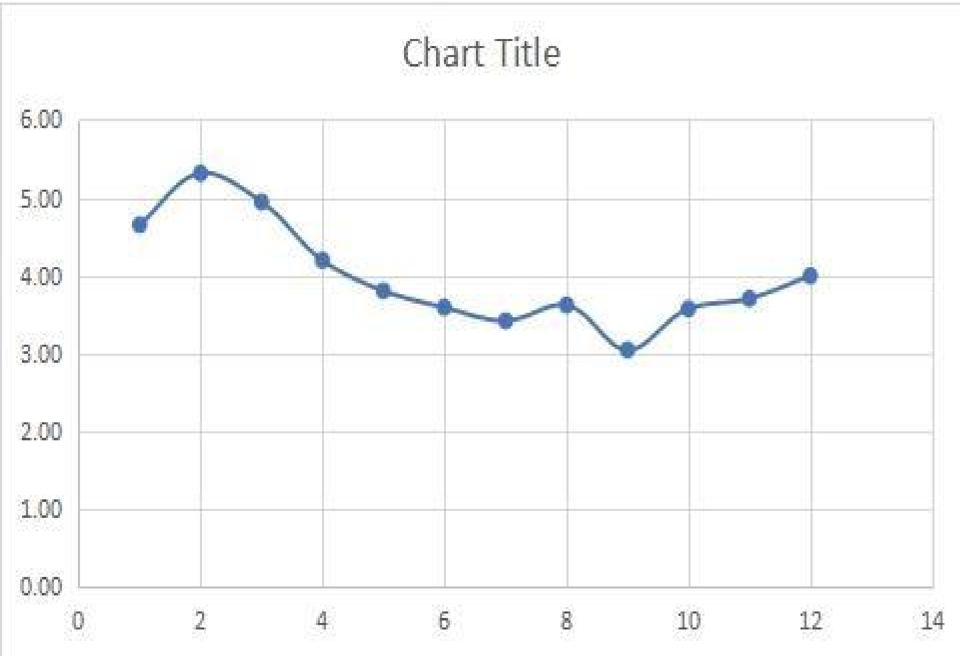

Fig. 4.2: Variation of monthly UV index for 2016

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Table 3: Monthly Time series of Solar Radiation for 2017

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	84310.55	4.53
Feb	84723.78	5.04
Mar	90380.66	4.86
Apr	86921.07	4.67
May	69605.37	3.74
Jun	63382.45	3.41
Jul	63635.61	3.42
Aug	68905.66	3.70
Sept	65082.64	3.50
Oct	82026.06	4.41
Nov	72176.35	3.88
Dec	80330.07	4.32

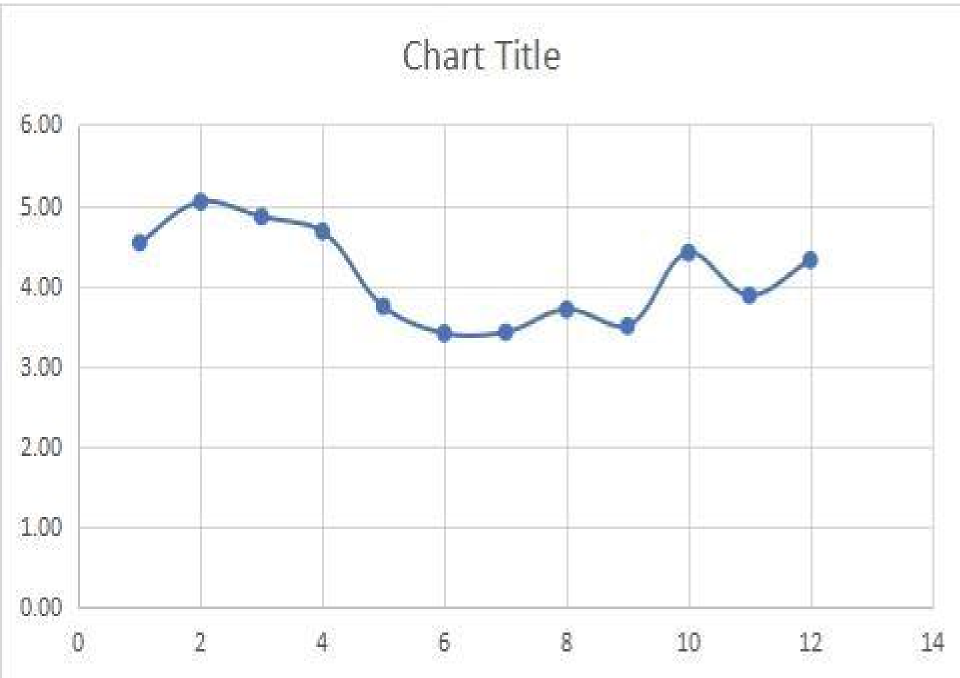

Fig.4.3: Variation of monthly UV index for 2017

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Table 4: Monthly Time series of Solar Radiation for 2018

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	88307.30	4.75
Feb	81196.44	4.83
Mar	82198.42	4.42
Apr	85590.68	4.60
May	75355.20	4.05
Jun	66869.53	3.60
Jul	66173.71	3.56
Aug	58163.22	3.13
Sept	56675.64	3.05
Oct	63355.77	3.41
Nov	65637.97	3.53
Dec	81110.88	4.36

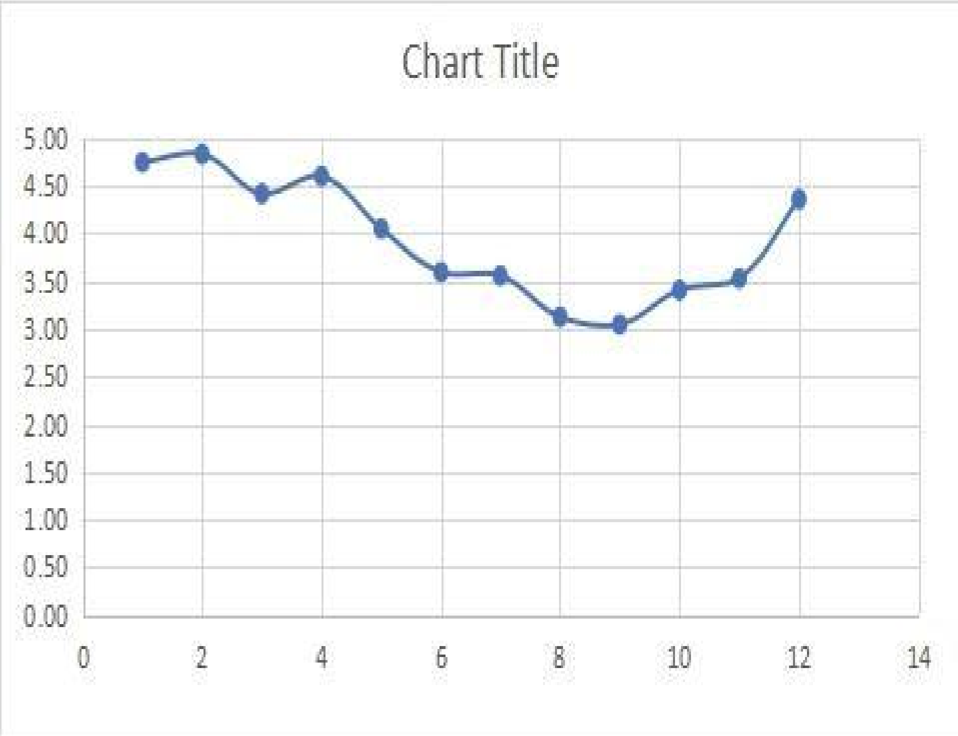

Fig. 4.4: Variation of monthly UV index for 2018

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Table 5: Monthly Time series of Solar Radiation for 2019

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	81098.61	4.36
Feb	82234.31	4.89
Mar	88192.88	4.74
Apr	83281.16	4.48
May	69176.31	3.72
Jun	63726.11	3.43
Jul	64237.01	3.45
Aug	63488.00	3.41
Sept	61217.42	3.29
Oct	57592.47	3.10
Nov	62847.30	3.38
Dec	65725.64	3.53

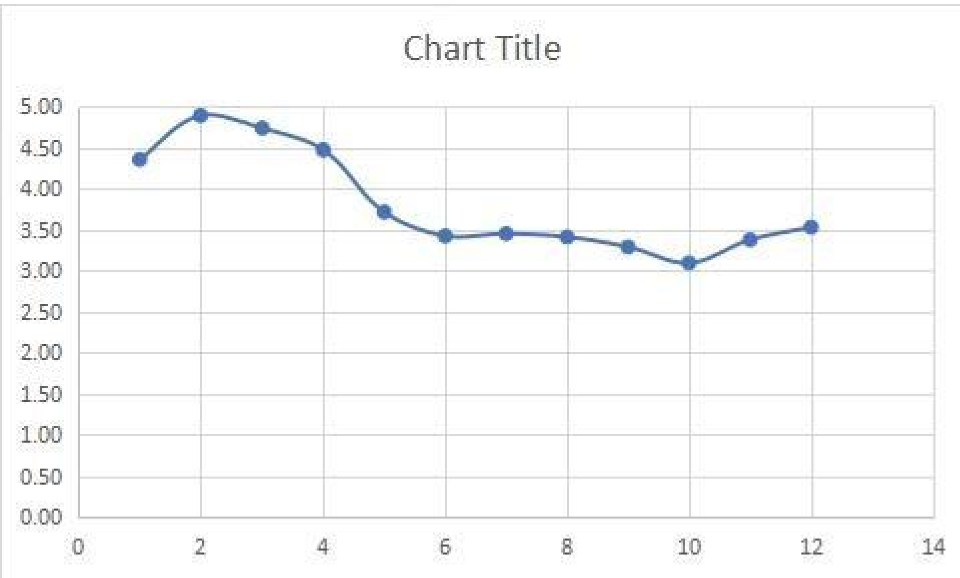

Fig. 4.5: Variation of monthly UV index for 2019

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Table 6: Monthly Time series of Solar Radiation for 2020 at …..(write the location here)

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	83307.19	4.48
Feb	89867.02	5.16
Mar	92208.66	4.96
Apr	79356.11	4.27
May	68568.51	3.69
Jun	65125.63	3.50
Jul	61197.17	3.29
Aug	64192.22	3.45
Sept	63954.18	3.44
Oct	65223.11	3.51
Nov	68527.98	3.68
Dec	68278.55	3.67

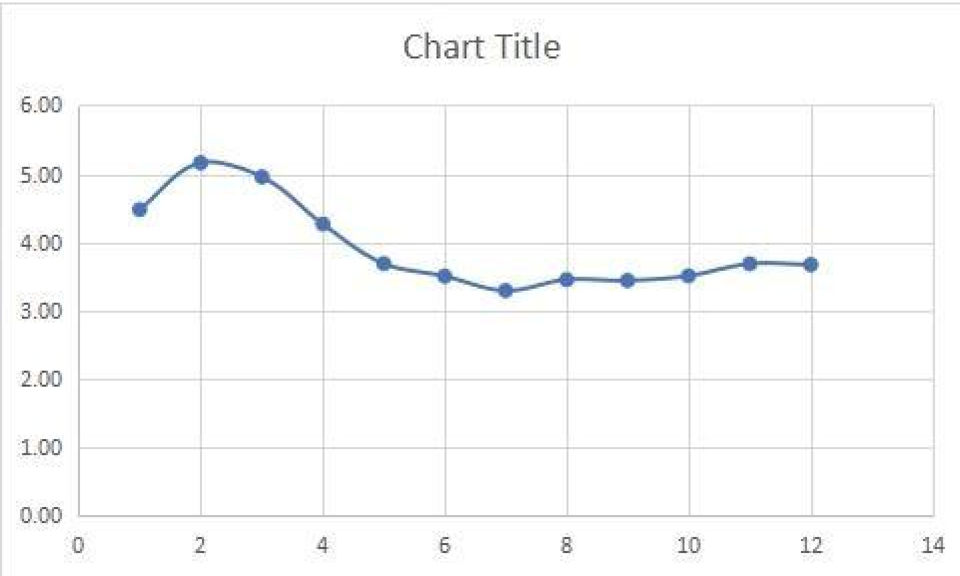

Fig. 4.6: Variation of monthly UV index for 2020

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Table 7: Monthly Time series of Solar Radiation for 2021 at …..(write the location here)

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	74111.21	3.98
Feb	77864.07	4.63
Mar	92060.58	4.95
Apr	86049.44	4.63
May	67822.41	3.65
Jun	57999.26	3.12
Jul	66077.52	3.55
Aug	55681.01	2.99
Sept	55790.43	3.00
Oct	64425.89	3.46
Nov	66422.03	3.57
Dec	75191.49	4.04

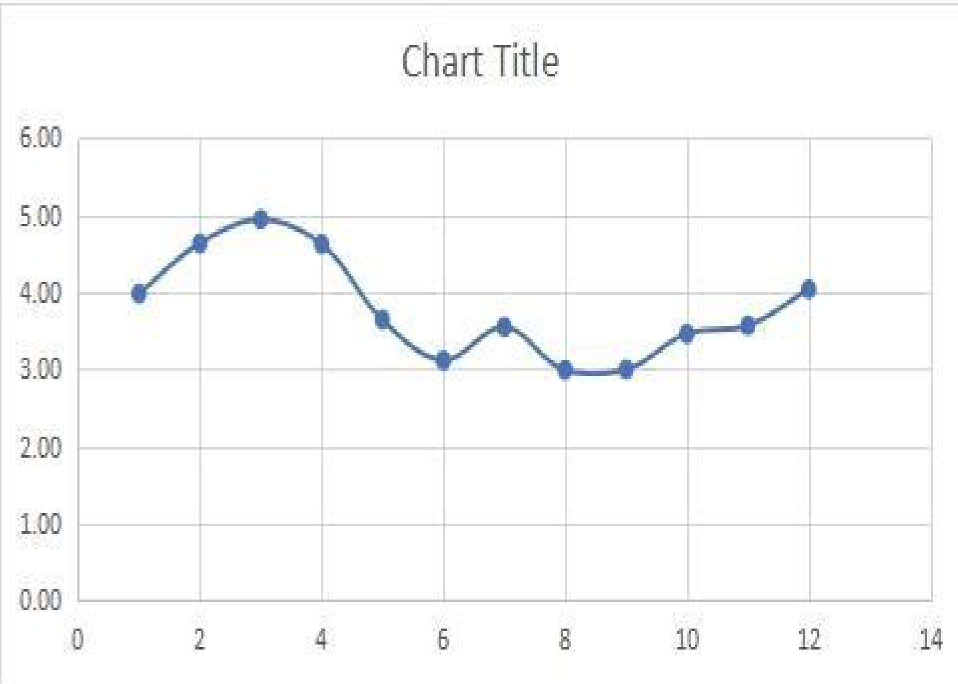

Fig. 4.7: Variation of monthly UV index for 2021

Table 8: Monthly Time - series of Solar Radiation for 2022 at …..(write the location here)

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	78647.23	4.23
Feb	75986.41	4.52
Mar	91473.55	4.92
Apr	75228.59	4.04
May	75766.25	4.07
Jun	64094.59	3.45
Jul	59288.48	3.19
Aug	65420.19	3.52
Sept	54114.04	2.91
Oct	72763.34	3.91
Nov	63977.32	3.44
Dec	67974.03	3.65

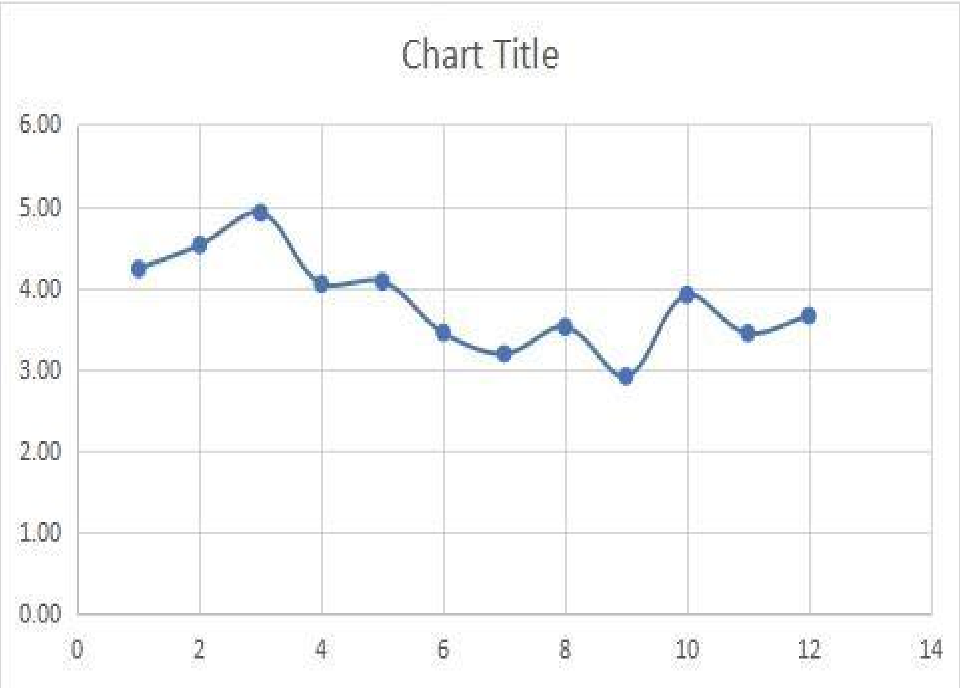

Fig. 4.8: Variation of monthly UV index for 2022

Table 9: Monthly Time - series of Solar Radiation for 2023

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	75582.17	4.50
Feb	76416.27	4.11
Mar	78807.89	4.24
Apr	81409.47	4.38
May	70729.06	3.80
Jun	61729.43	3.32
Jul	66396.77	3.57
Aug	76625.07	4.12
Sept	61881.37	3.33
Oct	70742.32	3.80
Nov	68722.92	3.69
Dec	74816.31	4.02

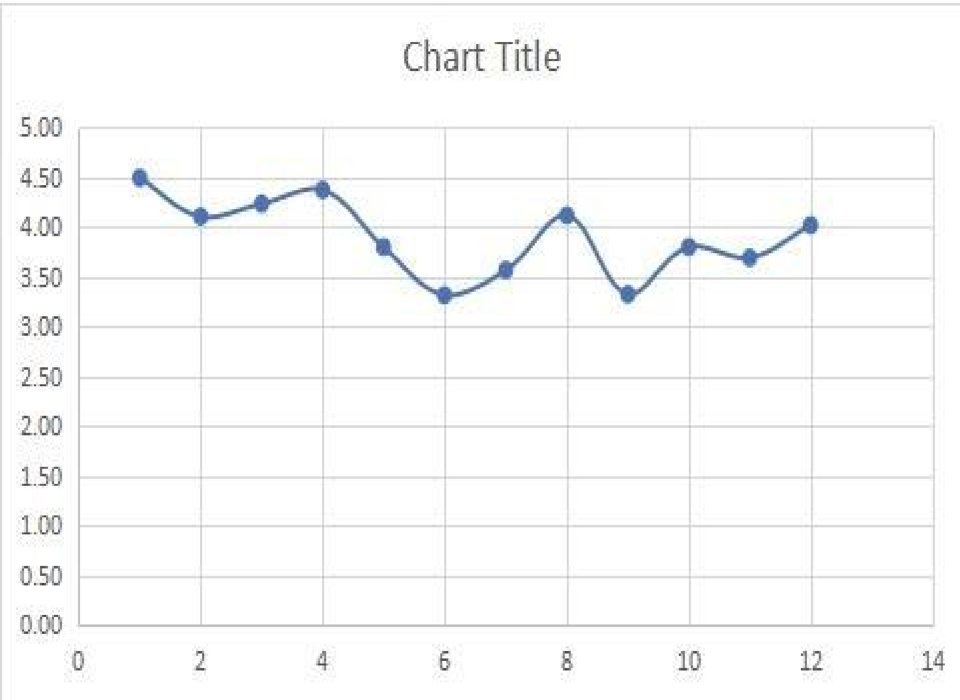

Fig. 4.9: Variation of monthly UV index for 2023

Table 10: Monthly Time - series of Solar Radiation for 2024

Observation Period	Clear Sky DHI (wh/m^2)	UV index
Jan	83504.34	4.49
Feb	91781.40	5.27
Mar	95091.09	5.11
Apr	82294.21	4.42
May	80480.41	4.33
Jun	68126.56	3.66
Jul	74093.03	3.98
Aug	75622.29	4.07
Sept	65848.98	3.54
Oct	65080.43	3.50
Nov	65730.96	3.53
Dec	76533.66	4.11

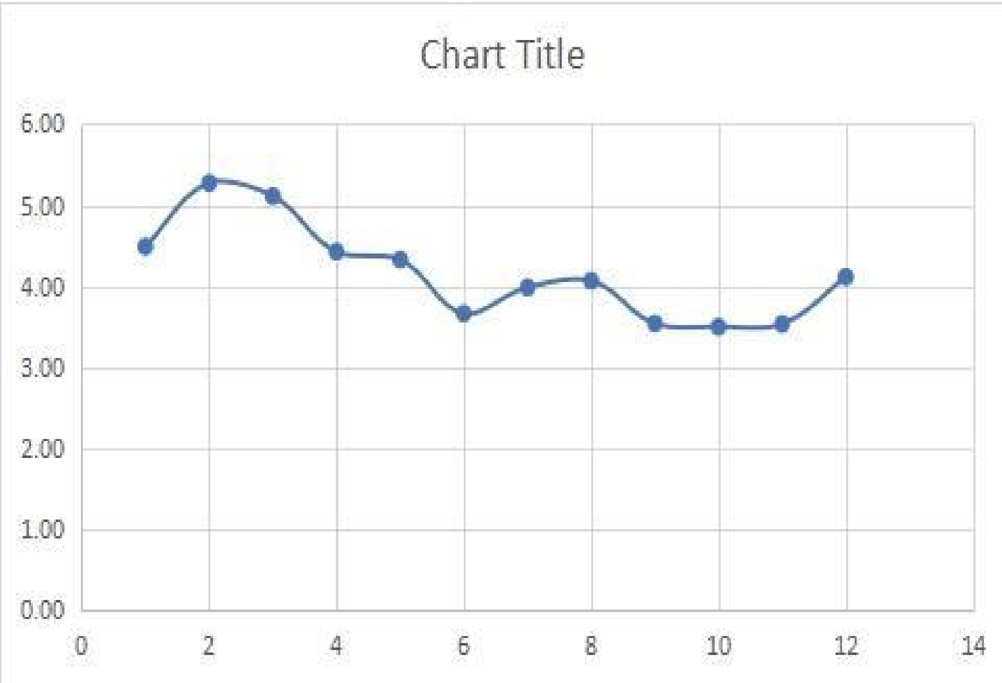

Fig. 4.10: Variation of monthly UV index for 2024

4.2 DISCUSSION

Chapter Four presents and interprets the data obtained from the Copernicus Atmospheric Monitoring Service (CAMS) for Benin City. The analysis focused on solar radiation parameters, Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI)**,** and the Ultraviolet Index (UVI) to understand their seasonal variation and health implications.

Findings revealed that **solar** radiation and UV index levels fluctuate significantly throughout the year, largely influenced by seasonal changes**.** The dry season (November–March) recorded the highest radiation intensity and UV index values (6.0–11.5)**,** corresponding to high to extreme exposure levels. In contrast, the rainy season (April–October) showed reduced UV levels due to increased cloud cover and atmospheric scattering. The data indicated that Benin City consistently experiences strong solar radiation, exposing residents, especially outdoor workers, to potential health risks such as sunburn, skin ageing, and nonmelanoma skin cancers. Graphical results confirmed that UV peaks align with clear-sky periods, while cloud cover moderates exposure.

In summary, Chapter Four establishes that Benin City lies within a high UV radiation zone**,** and continuous exposure without protection poses a significant public health concern.

CHAPTER FIVE

5.1 CONCLUSION

This study concludes that Benin City experiences consistently high levels of solar and ultraviolet (UV) radiation, with intensity varying seasonally, highest in the dry season and lowest in the rainy season. The UV Index values, ranging from 6.0 to 11.5, indicate persistent high to extreme exposure levels that pose significant health risks, including skin damage and non-melanoma skin cancers, particularly among outdoor workers. The research highlights low public awareness, inadequate protective practices, and the absence of UV monitoring systems as major challenges. It therefore recommends the establishment of routine UV monitoring by relevant agencies, increased public education on sun safety, policy integration of UV protection in occupational health standards, and further studies linking UV exposure to skin cancer prevalence in Nigeria.

Overall, the study underscores the urgent need for coordinated environmental and health interventions to mitigate the harmful effects of excessive solar UV radiation in Benin City and similar tropical regions.

5.2 RECOMMENDATION

Based on the findings from the characterisation of solar radiation and UV index in Benin City and their implications for skin cancer among exposed individuals, the following recommendations are made:

1. **Public Awareness and Education:**
   There is a strong need for continuous public enlightenment on the health effects of excessive solar and UV exposure. Local health agencies, NGOs, and media outlets should collaborate to sensitise residents about daily UV levels, safe sun exposure times, and protective habits such as wearing hats, long-sleeved clothing, and applying sunscreen.
2. **Implementation of UV Index Forecasts:**
   Meteorological agencies in Nigeria should integrate daily UV index forecasts into regular weather reports, similar to practices in developed countries. This will help the public plan outdoor activities based on real-time UV risk levels.
3. **Promotion of Protective Infrastructure:**
   Urban planners and government bodies should ensure the provision of shaded structures in markets, bus stops, schools, and recreational areas to minimise direct exposure, particularly for outdoor workers and vulnerable populations.
4. **Occupational Health Policies:**
   Employers of outdoor workers, such as construction firms, agricultural bodies, and transport services, should adopt occupational health guidelines that limit sun exposure

during peak radiation hours (10 a.m. to 3 p.m.). Provision of protective gear and mandatory rest breaks in shaded areas should be enforced.

5. **Integration of Sun-Safety into School Curricula:**
   Educational institutions should introduce topics on solar radiation, UV risks, and preventive measures into science and health education at all levels. Early awareness will foster lifelong sun-safe behaviour.
6. **Encouragement of Sunscreen Use and Local Production:**
   Government and private sectors should promote the affordability and availability of broad-spectrum sunscreens. Local pharmaceutical companies could be encouraged to develop cost-effective formulations suited to the Nigerian climate.
7. **Strengthening Environmental Protection Policies:**
   National and regional environmental authorities should uphold international agreements such as the Montreal Protocol to preserve the ozone layer. Reduced ozone depletion directly translates to lower UV radiation reaching the Earth's surface.
8. **Further Research and Continuous Monitoring:**
   There should be sustained research on solar radiation variability, ozone levels, and UV-related diseases using long-term data from sources such as the Copernicus Atmospheric Monitoring Service (CAMS). This will enable evidence-based policymaking and improve local climate-health adaptation strategies.
9. **Medical Screening and Early Detection:**
   Health institutions should conduct periodic skin examinations and establish specialised dermatology centres for early detection and management of UV-induced skin conditions, particularly among outdoor workers and albino populations.

Implementing these recommendations requires a multi-sectoral approach involving government agencies, researchers, healthcare professionals, and the general public. By combining public education, policy action, and continued environmental monitoring, Benin City and similar tropical regions can significantly reduce the health risks associated with high UV radiation exposure.

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