**Original Research Article**

**Effect of dirt on Solar Photovoltaic Cell performance In Umuseti, Kwale, Delta State, Nigeria**

**ABSTRACT**

This paper presents an investigation into the effect of dirt on the performance of solar photovoltaic systems in Umuseti, Kwale, Delta State, Nigeria. The experiment used two separate 250 W monocrystalline solar panels in the Umuseti community near the Pillar Oil Flow Station and Energia Flow Station. One of the solar panels was left exposed to impurities, while the other was cleaned weekly to prevent dirt accumulation on its surface. This arrangement aims to study the impact of dirt accumulation on the power output of solar panels with and without impurities. Readings on the panels were taken regularly and recorded consecutively for one year (September 2023 – August 2024). The daily average voltage and power data were analyzed alongside the daily average percentage reduction in voltage and power efficiency. The results indicate that the climatic conditions of the environment (Umuseti, Kwale, Delta State) significantly influence the efficiency of the solar panels, both with and without cleaning. The highest voltage observed for the cleaned solar panel was recorded in November at 29.34 V, while the lowest was in August at 26 V. The cleaned solar panel produced an average daily power of 217 W, while the uncleaned panel generated a daily average power of 199 W. The daily average percentage reduction in power observed during the study was 48%. Results suggested that during periods of low or no rainfall (November 2023- April 2024), when solar intensity was high, higher voltage and power values were recorded compared to the low solar intensity period (May 2023- September 2024), which saw a gradual decrease in voltage output. Continuous cleaning is necessary; however, during the rainy season, regular cleaning is unnecessary, as rain naturally cleans the solar panel while also cooling it for maximum efficiency.

***Keywords****: PV cells, Solar panels, Dust particles, power efficiency, voltage efficiency, panel maintenance,*

**1 INTRODUCTION**

Energy plays a crucial role in our daily activities. The amount of energy consumed by a country's citizens determines its level of development and civilization. Energy demand increases daily due to population growth, urbanization, and industrialization [1]. Various forms of energy can be harnessed and stored in different ways. Energy sources are classified into two categories: renewable (an energy source that can be utilized continuously) and non-renewable (an energy source that, once depleted, cannot be recreated in a short time) [2]. Renewable energy is essential in reducing carbon emissions, thus helping to decrease greenhouse gases [3]. Solar cells are devices capable of converting sunlight into electricity [4]. They are environmentally friendly because they do not produce greenhouse gases, contributing to the mitigation of global warming [4]

 Solar photovoltaic (PV) energy systems are classified as renewable energy and have various components, each serving a specific role [5]. The type of system and its purpose determine the kinds of components used [5]. For instance, a simple PV-direct system includes a solar panel and the load (energy-using device) its powers [5]. Submersible water pumps and ventilation fans are among the most used loads [5]. Stand-alone systems that include energy storage typically contain more components than a PV-direct system [5]. Solar photovoltaic systems primarily operate in outdoor environments, where they are often connected directly, frequently without protective coverings. This results in significant responses to wind speed, temperature, solar radiation, humidity, and dust accumulation [6]. It is important to note that these factors often substantially reduce the efficiency of photovoltaic systems [7]. Additionally, dust accumulation causes a marked decrease in the intensity of solar irradiation reaching the surface of the solar panel, resulting in inefficient conversion of solar energy into electricity [8]. Research has also shown that the location of PV modules influences both the level of pollution and the amount of dust accumulation on the solar panel's surface [9]. Factors such as particle size, the quantity of suspended particles, and atmospheric conditions are crucial in determining the rate of dust accumulation on a PV system, though these can vary by site [4]. The duration of exposure to external conditions also affects the amount of dust that accumulates on solar panel surfaces [4].

 Two major interdependent parameters influence the characterization of particles that collect on the surface of solar photovoltaic panels [10]. These are the properties of dust particles and the local environment where the solar photovoltaic panel is installed. Dust properties include the size, source, and weight of the particles. For instance, particles containing acidic components can gradually erode the surface of the photovoltaic panel [11]. According to studies, the distribution of the size of suspended particles collected on the surface of the solar PV cell due to dust is critically significant and has a linear effect on the degradation of solar cell efficiency [12]. The dispersion, reflection, and absorption of light on solar panels, in addition to how solar panels interact with wind speed, are influenced by the size of suspended particles from dust accumulation [4]. Research conducted by [13] revealed that dust particles accumulating on the surface of photovoltaic systems ranged in size from one to fifty millimeters in diameter.

 The local environment includes surrounding weather conditions, vegetation, and human activities such as exploration, construction, and production, all of which can directly or indirectly affect the performance of solar photovoltaic panels. It has been observed that a smooth surface reduces dust particle accumulation compared to a rough, sticky surface [14]. The installation position, determined by the direction of sunlight for optimal absorption of solar irradiance and wind direction, significantly impacts dirt accumulation on the surface of solar photovoltaic panels. Research has shown that the more horizontal a solar panel is, the greater the tendency for dirt to accumulate on its surface [15]. Additionally, mild wind can contribute to dirt accumulation on panel surfaces, while strong wind results in less accumulation due to its ability to displace dirt.

 This paper presents an experiment on dust characteristics and their effect on the performance of solar photovoltaic modules over six months. The observed morphology of the dust particles indicates they vary in shape and size, ranging from 1.61 to 38.40µm. The findings reveal a linear relationship between dust density and the power output of the photovoltaic module, indicating a reduction of 1.7% per g/m². Moreover, it was reported that dust accumulation depends on the tilt angle of the solar photovoltaic module. According to the report, for tilt angles of 0 °, 25 °, and 45 °, the dust accumulation measured 37.63%, 14.11%, and 10.95%, respectively.

**1.1 LITERATURE REVIEW**

Over the years, solar production has dropped due to lack of frequent maintenance involving cleaning the panels of accumulated dust particles especially in areas where industries are situated. Research has been carried out to assess the effects of dirt on solar PV cells by putting in place some measures to clean the panels for an optimized power output. Most panels are meant to generate more power at peak period when the sun intensity is high but are curtailed due to soiling resulting from accumulated dust particles not cleaned. This section presents a summary of related literature that is available regarding the analysis of dirt on solar PV cells and its solution model in the optimization of solar panels output.

 A report by [17] on the angular dependencies of soiling loss (dust) affecting the performance of photovoltaic systems in Nigeria, using different orientations (horizontal, 45 ° tilt, vertical), shows that the horizontal position has the greatest reduction in transmittance, approximately 88%, while the vertical position has the least reduction, about 1%. The report concludes that the horizontal positioning of solar photovoltaic panels significantly increases the rate of dust deposition, which progressively decreases as the tilt angle approaches a vertical position.

 A study by [18] on the environmental impacts of solar photovoltaic panels indicated that dust accumulation reduces the power output of the photovoltaic panels by 8.8%, whereas efficiency decreases by 11.86%.

 An experiment conducted by [15] aimed to evaluate the effects of particle sizes and tilt angles on dust deposition characteristics of ground-mounted solar photovoltaic panels, using various tilt angles of 25 °, 40 °, 140 °, and 155 °. Results showed deposition rates of 14. 14.38%, 13. 53%, 6. 79%, and 9. 78% for dust particles on the surfaces of the solar photovoltaic panels. It was concluded that dust deposition is higher when PV panels are installed facing upwards compared to when they are placed downwards.

 [19] In their study on the evaluation of dust deposits on solar photovoltaic panels, they concluded that dust accumulation can reduce the efficiency of these panels by up to 30-50%.

 A study by [20] shows that several factors contribute to dust deposition on solar panels. It reported that the properties (size, shape, and chemical composition) of dust particles, characteristics of photovoltaic panels (tilt angle, orientation), and environmental conditions (wind speed, dust concentration, weather conditions, location, and distance to the dust source) significantly impact the rate of dust deposition on the surfaces of solar panels.

Although several other studies have examined the effects of dust particles and impurities on the performance of photovoltaic systems, no documented reports of such a study have been found in Umuseti, Delta State, Nigeria, which is located near oil flow stations. In addition to dust, the accumulation of soot particles in the Umuseti environment is typical. Given this context, the present research focuses on the effects of dirt on the performance of the photovoltaic system in Umuseti, Kwale, Delta State, Nigeria.

**2. MATERIAL AND METHODS**

 The experiment used two separate 250W monocrystalline solar panels and two digital multimeters to take readings. The specifications of the solar panels and the digital multimeters are as shown below.

**Table 1** Specification of the Solar Panel

|  |  |
| --- | --- |
| **Model** | **LDK 250D-20** |
| Peak Power (W) | 250 |
| Maximum Power Voltage (V) | 30.5 |
| Maximum Power Current (A) | 8.20 |
| Open Circuit Voltage-VoC (V) | 37.8 |
| Short Circuit Current-ISC (A) | 8.9 |
| Module Efficiency | 15.3 |
| Weight | 19.5kg |
| Module dimension | 1650x992x40mm |

**Table 2** Specification of the Multimeter

|  |  |
| --- | --- |
| **Model** | **DT9205A** |
| AC Voltage (V) range | 2V, 20V, 200V, 750V. |
| DC Voltage (V) | 200mV, 2V, 20V, 200V, 1000V. |
| AC Current (A) | 2mA, 200mA, 20A |
| DC Current (A) | 20µA, 2mA, 200mA, 20A. |
| Resistance (Ohm) | 200Ω, 2kΩ, 20kΩ, 200kΩ, 2MΩ, 200MΩ, 200MΩ. |
| Maximum Value display | 1999 |
| LCD | Bright and clear and easily visible |
| Capacitance (F) | 20nF, 2µF, 20µF, 200µF. |

**2.1 Data Collection**

One of the Solar Panels was left exposed to dirt on its surface while the other was adequately cleaned every week to ensure that there was no dirt deposit on its surface. This was done to observe the variation in the Solar Panel's power output with and without particles settling on them. Hourly readings were taken and collated accordingly for a period of one year (September 2023 – August 2024). Table 3 shows the Average daily Voltage, Power, percentage reduction in Voltage, and Percentage reduction in Power of the Solar Photovoltaic Panel with and without impurities on the Solar Photovoltaic Panels.

**Table 3:** Daily average Voltage, Power, and Percentage reduction in Voltage and Power of PV with and without cleaning for the period (September 2023- August 2024).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Months** | **Average Voltage****(With Cleaning)****(V)** | **Average Voltage****(Without Cleaning)****(V)** | **Average****Power****(With Cleaning)****(W)** | **Average****Power****(Without Cleaning)****(W)** | **Voltage reduction****%Vr** | **Power Efficiency Reduction****%Pr** |
| Sept  | 27.78 | 26.97 | 205.70 | 198.84 | 2.92 | 3.34 |
| Oct | 28.20 | 27.84 | 210.27 | 203.90 | 1.28 | 3.03 |
| Nov | 29.34 | 28.90 | 221.90 | 209.46 | 1.5 | 5.61 |
| Dec | 29.27 | 28.84 | 233.45 | 212.28 | 1.47 | 9.07 |
| Jan | 29.07 | 28.78 | 230.03 | 208.78 | 1.0 | 9.24 |
| Feb | 29.05 | 28.86 | 231.02 | 210.19 | 0.66 | 9.02 |
| Mar | 29.02 | 28.73 | 231.13 | 209.03 | 1.0 | 9.57 |
| April | 29.0 | 28.82 | 232.52 | 208.42 | 0.63 | 10.37 |
| May | 27.72 | 26.97 | 208.10 | 196.03 | 2.71 | 5.81 |
| June | 27.12 | 25.68 | 207.10 | 185.92 | 5.31 | 10.23 |
| July | 27.22 | 24.93 | 202.89 | 175.48 | 8.42 | 13.51 |
| August | 26.75 | 24.4 | 200.31 | 174.40 | 8.79 | 12.94 |
| Avg | 28.30 | 27.48 | 217.87 | 199.39 | 2.97 | 8.48 |

**3 RESULTS AND DISCUSSION**

The Results from table 3 show that the daily average voltage and power generated for the solar panel without the presence of impurities is higher than for the photovoltaic module with impurity. The reason for this is because the solar panel with impurities interfered with the incident sunlight, thus scattering the light path for direct penetration. The Solar panel with continuous cleaning produces a daily average Power of 217.87W while the solar panel without cleaning produces a daily average Power of 199.39W. The daily average percentage reduction in power observed during the duration of the study was 8.48%, and it was due to the dust deposits on the surface of the solar panel that were not cleaned. The observed power reduction during the period of study may also be affected by the Climatic condition at the time the sampling was carried out.

**Fig 1**: Average voltage with and without cleaning.

**Fig 2**: Average Power with and without cleaning.

**3.1 Result analysis**

Figures 1 and 2 illustrate the variation in average voltage and power for the solar panel with cleaning compared to the solar panel without cleaning from September 2023 to August 2024. The highest voltage observed for the solar panel with cleaning occurred in November, reaching a recorded value of 29.34V, while the lowest voltage was noted in August at 26.75V. This indicates that the climatic conditions in November are more favorable for energy generation by the solar panel, whereas conditions in August are the least favorable due to low solar irradiance during that period. This finding aligns with the standard report which noted high solar irradiance from November to April and low solar irradiance from May to September in Ogwashi-Ukwu Town, Delta State. For the solar panel without cleaning, the highest observed voltage (28.90V) was also in November, with the lowest observed voltage (24.40V) in August.

 Analysis of the results shows that both the solar panels, with and without cleaning, exhibit higher voltages from November 2023 to April 2024 and lower voltages from May to August 2024 due to climatic conditions (low solar intensity) during these periods. Additionally, the solar panel with continuous cleaning generates higher voltage compared to the solar panel without cleaning. The observed lower voltage in the uncleaned solar panel is attributed to dirt accumulation, which limits solar irradiance on its surface. Furthermore, during dry periods, a gradual buildup of dirt on the panel occurs, and without cleaning, solar irradiation is restricted because dirt diminishes the maximum capture of solar irradiation. Increased heat generation without cooling also gradually reduces the efficiency of the solar panel. This trend is further evidenced by the percentage reduction in voltage and power, as illustrated in Figures 1 and 2.

Fig 3. Percentage reduction in Voltage

Fig 4. Percentage reduction in Power

The period from July to August shows the highest reduction in voltage and power. This may be attributed to the long-term buildup of dirt on the surface of the solar Panel, thus limiting the amount of solar irradiance that can be absorbed. In addition, during this period the amount of solar irradiance is usually low, therefore, the available energy that can be captured is being reflected by the dirt on the surface of the Panel, because the Panel was set up without cleaning in an area (Umuseti, Kwale) that has a concentration of Oil Companies that generates soot capable of contaminating the Solar Panel as a result of the gas flaring activities.

**3.1 Discussions**

The findings of this study confirm that dirt accumulation—comprising dust and soot particles—significantly affects the performance of photovoltaic systems in Umuseti, Kwale, Delta State. The data indicate an average power output reduction of 8.48% and a voltage drop of 2.97% in panels that are not cleaned regularly. These results align with prior research by Kazem et al. (2014) and Hachicha et al. (2019), which reported similar declines in power output due to environmental soiling. The seasonal variation observed in the study further highlights the influence of climate on PV efficiency; during the dry season (November to April), reduced rainfall leads to more significant dirt accumulation, resulting in noticeable performance degradation. Conversely, the rainy season (May to September) facilitates natural cleaning through rainfall, mitigating dirt buildup and improving power output. This reinforces the conclusion that periodic manual cleaning is essential during the dry months, while a reduced cleaning frequency may be acceptable during wetter periods. Furthermore, the proximity of the study area to oil and gas operations introduces soot-related contamination, which is less common in conventional dust studies and presents a unique regional concern. Although the current study focused on manual weekly cleaning, it also underscores the potential for future improvements through automated or water-efficient cleaning systems, particularly for locations with persistent pollution sources. By quantifying energy losses and identifying local environmental factors, this research provides a practical foundation for optimising maintenance strategies in similar climatic and industrial settings.

**4. CONCLUSION**

The present study was conducted to gain preliminary insight into the influence of dirt deposition on photovoltaic system performance in Umuseti and its Environs, Kwale, Delta State. A comparative analysis of the results led to an understanding of the phenomenon of power loss due to dirt (petroleum soot and dust) accumulation on photovoltaic surfaces.

 The prevailing climatic condition of the environment is essential in studying the effect of dirt deposit on Solar Panels. The period of low or no rainfall with high heat intensity produces maximum voltage. If the solar panel is not cleaned, during this period, cleaning is needed continuously, but during the period of rainfall, minimal cleaning or no cleaning is required because the rain naturally cleans the solar panel and produces a cooling effect, which helps to maximize the power output.

 Dirt deposition significantly alters the voltage and power output of photovoltaic systems. This study observed a voltage reduction and power reduction of 2.97% and 8.48%, respectively. This drop in voltage output and the consequent drop in power output due to dirt deposit on the surface of the solar Panel is an immense loss of electrical power and economic loss to the photovoltaic power system.

 Generally, in the Umuseti region, there is supposed to be high Solar irradiance from November to April. Thus, continuous cleaning (weekly) of the Panel should be adopted because it was observed that the Solar Panel without cleaning produces lower voltage and power values due to dirt deposits during this period. Additionally, from May to September, when there is rainfall, cleaning may be affected once every two weeks.

REFERENCES

[1] C.K. Amuzuvi and E. Effah. “Design of a photovoltaic system as an alternative source of electrical energy for powering the lighting circuits for premises in Ghana”. Journal of Electrical and Electronic Engineering. vol.2, no.1, pp 9-16, 2014.

[2] J. Singh. “Study and Design of Grid connected Solar PV system at Patiala”. Unpublished MSc Thesis Report, Thapia University, Patiala – India, pp 1-94, 2010.

[3] S.K. Gupta and P. Purohit. “Renewable energy certificate mechanism in India: a preliminary assessment”. Renewable and Sustainable Energy Reviews, vol.2, no.2, pp 380-392, 2013.

[4] M. T. Chaichan, Hussein, A. Kazem, Ali H.A. Al-Waeli, and K. Sopian. “The effect of dust components and contaminants on the performance of photovoltaic for the four regions in Iraq: a practical study”. Renew. Energy Environ. Sustain. vol.5, no.3, pp 8-12, 2020.

[5] A.K. Soteris. “Photovoltaic Systems”. Solar Energy Engineering*.* Pp 1-7, 2014.

[6] H. A. Kazem and M. T. Chaichan. “Effect of humidity on photovoltaic performance based on experimental study”. International Journal of Applied Engineering Research (IJAER), vol.10, no.23, pp 43572-43577, 2015.

[7] A. H. Al-Waeli, K. Sopian, M. T. Chaichan, H. A. Kazem, A. Ibrahim, S. Mat, and M. H. Ruslan. “Evaluation of the nanofluid and nano-PCM based photovoltaic thermal (PVT) system: An experimental study”. Energy Conversion and Management, vol.15, no.1, pp 693-708, 2017.

[8] Z. A. Darwish, H. A. Kazem, K.Sopian, M. A., Al-Goul and H. Alawadhi. “Effect of dust pollutant type on photovoltaic performance”. Renewable and Sustainable Energy Reviews, vol.4, no.1, pp 735-744, 2015.

[9] J. Tanesab, D.Parlevliet, J.Whale, T. Urmee and T. Pryor. “The contribution of dust to performance degradation of PV modules in a temperate climate zone”. Solar Energy, vol.1, no.20, pp 147-157, 2015.

[10] A. A. Hachicha, I. Al-Sawafta, and Z. Said. “Impact of dust on the performance of solar photovoltaic (PV) systems under United Arab Emirates weather conditions”. Renewable Energy, vol.14, no.1, pp 287-297, 2019.

[11] A. K. Sisodia, and R. K. Mathur. “Impact of bird dropping deposition on solar photovoltaic module performance: a systematic study in Western Rajasthan”. Environmental Science and Pollution Research, vol.26, no.30, pp 31119-31132, 2019.

[12] S. Pulipaka, F. Mani and R. Kumar. “Modeling of soiled PV module with neural networks and regression using particle size composition”. Solar Energy, vol.12, no.3, pp 116-126, 2016.

[13] E.Adiguzel, E.Ozer, A.Akgundogdu and A.Ersoy. “Prediction of Dust Particle size effect on efficiency of photovoltaic modules with ANFIS: An experimental study in Aegean region, Turkey”. Solar Energy, vol.17, no.7, pp 690-702.

[14] D. Goossens. “Wind tunnel protocol to study the effects of anti-soiling and anti-reflective coatings on deposition, removal, and accumulation of dust on photovoltaic surfaces and consequences for optical transmittance”. Solar Energy, vol.16, no.3, pp 131-139, 2018.

[15] H. Lu and W. Zhao. “Effects of particle sizes and tilt angles on dust deposition characteristics of a ground-mounted solar photovoltaic system”. Applied Energy, vol.2, no.20, pp 514-526, 2018.

[16] M. Jaszczur, A. Koshti, W. Nawrot, and P. Sędor. “An investigation of the dust accumulation on photovoltaic panels”. Environmental Science and Pollution Research, vol.27, no.2, pp 2001-2014, 2020.

[17] Y.N. Chanchanji, A. Ghosh, S. Sundaram and T.K. Mallick. “Angular dependencies of soiling loss on photovoltaic performance in Nigeria”. Solar Energy, vol. 22, no.5, pp 108-121, 2021.

[18] R. J. Mustafa, M. R. Gomaa, M. Al-Dhaifallah, and H.Rezk. “Environmental impacts on the performance of solar photovoltaic systems”. Sustainability, vol.12, no.2, pp. 608. 2020

[19] O. Chukwuekum, and O. S. Oseme. “Solar cell cleaning and efficiency performance analysis on dust particles accumulation on solar panel in Nigeria. A case study of Northern Nigeria”. Journal of Sustainable Energy & Environment, vol.1, no.1, 135-141, 2020.

[20] D. I. Paul. “Dust Deposition on Photovoltaic Modules: Its Effects on Performance”. In The Effects of Dust and Heat on Photovoltaic Modules: Impacts and Solutions Springer, Cham*.* Pp 3-46, 2022.

[21] H. A. Kazem and M. T. Chaichan. “Effect of humidity on photovoltaic performance based on experimental study”. International Journal of Applied Engineering Research (IJAER), vol.10, no.23, pp 43572-43577, 2015.

[22] E.C. Obuah and T.J. Alalibo. “Effect of Black Soot on the Performance of Photovoltaic Systems in Port Harcourt”. IRE Journals, vol. 2, no.6, pp 63-66, 2018.