COVID -19 Pandemic Effect on the Solar Irradiance: Case Study Ma`an Development Area

AHLAM. M. ALSAIDAT, MOHAMED R. GOMAA, *
Mechanical Engineering Department
Faculty of Engineering, Al-Hussein Bin Talal University
Maan, 71110 Maan
JORDAN

Abstract: - Solar Photovoltaic (PV) Panels are converting solar radiation into an electrical form of energy, the performance, and efficiency of PV Panels are affected by several factors including environmental factors represented by air pollutants) typically includes PM10, fine PM2.5, NOx, Sox, and dust), as many studies have found that the efficiency of PV panels cell decrease when the concentration of air pollutant increase, in these study Air pollutant concentration and solar radiation data, were collected during the COVID-19 Pandemic, the result showed that a huge decrease in air pollutant concertation in Jordanian cities and slightly change in the percentage of solar radiation in study area MDA, the recommend to do the study again in an industrial or densely populated area, where pollution rates will be greater, which means a greater impact on the efficiency of solar PV Panels.

Key-Words: - COVID-19 Pandemic; Solar Photovoltaic; Panels Efficiency; Air Pollutants; MDA

Received: September 29, 2021. Revised: October 7, 2022. Accepted: November 16, 2022. Published: December 29, 2022.

1 Introduction

Solar energy is one of the major sources of renewable energy; it is free and clean. Renewable Energy in many countries produces an important share of the total energy production, Photovoltaic (PV) system is a renewable energy system, which converts the sunlight directly into electricity, the heart of a photovoltaic system is a solid-state device called a solar cell [1-6]. In 2019, PV generated 8.2% of gross electricity consumption with an electricity generation of about 46.5 TWh in Germany [7]. When light shines on a PV cell, it may be reflected, absorbed, or pass right through. But only the absorbed light generates electricity [1]. The performance of the solar modules is influenced by various factors such as the material the module is manufactured of, the angle of inclination of the solar module, the intensity of the solar radiation reaching the surface of the module, soiling of the module surface, module temperature, etc. Soiling is a term used to describe the deposition of dust on solar modules, which reduces the amount of solar radiation reaching the solar cells [8-11].

Jaszczur et al. and other researchers said that the performance of the photovoltaic modules is affected by several environmental factors such as wind speed, ambient temperature, humidity, rainfall, incident solar radiation intensity, and spectrum, dust deposition, pollution and shadowing [12-15].

In the present study, the authors focus on the relationship between one of the Environmental Factors “air pollutants” and solar radiation incidents on PV modules during the COVED-19 Pandemic.

1.1 COVED-19 Pandemic

COVID-19 (Corona Virus Disease 2019) was reported in December 2019 in Wuhan, due to its fast spread across the world Health Organization (WHO) stated the COVID-19 outbreak as a “Pandemic public health menace” On March 11, 2020 [16].

The COVID-19 pandemic not only affects public health but also stopped life around the world, many sectors were affected by the pandemic, such as/*036 global economic growth, education, and the environment, the world economy was negatively affected due to the stop of economic activities as a result of restriction movement and transportation to control the spread of the pandemic, as a result of decreasing economic activities, air pollutions percent are reducing.

1.2 COVID-19 Pandemic Effect on Air Pollutions rate in Jordan

Many countries of the world have taken the decision to lockdowns most sectors to prevent the COVID-19 Pandemic's spread. Cheval et. al [17] indicate that at the end of March 2020, reductions in air pollution were reported in China, Italy, and New York City, Moreover, an overview focused on several European countries reveals that the reduction of the weekly NO_2, PM10, and PM2.5 concentrations during March and April 2020 is quasi general. Fig. 1 registered by the European Space Agency clearly shows how a strong reduction in emissions is now in place over major cities across Europe - in particular Paris, Milan, and Madrid.

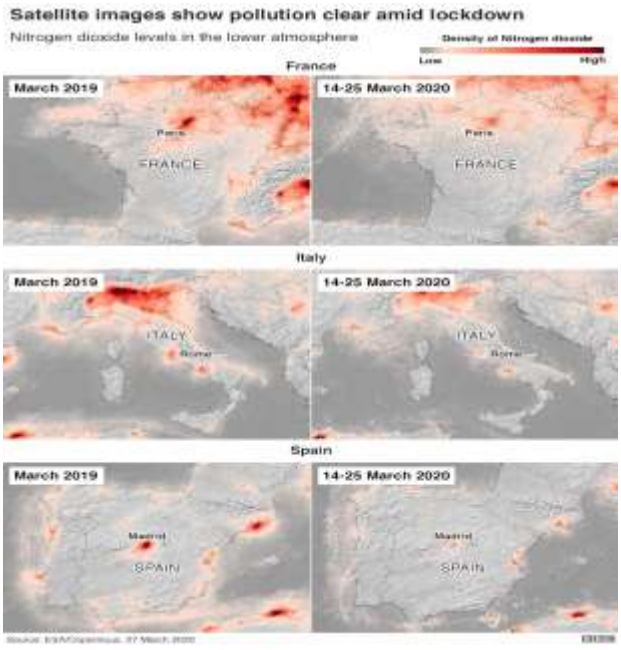

Fig. 1 Pollutants during the COVID-19 pandemic

In Jordan, the environmental monitoring and assessment directorate/ministry of an environment prepared a study entitled "reduction of pollutants in the ambient air in Amman, Irbid, and Zarqa as a result of government actions taken from 15/3/2020 to 15/4/2020 to respond to the Coronavirus (COVID-19) Pandemic".

The period from 15/3/2020 to 15/4/2020, which was the period when government measures were enforced, included a partial and comprehensive lockdown to deal with the new COVID-19 pandemic, the data were compared with the same period last year and also with the period of a month before the crisis (14/2/2020 to 14/3/2020) [18].

The study showed that the average rate of decline in the daily rates of PM10, taking into account the impact of dust storms recorded by ambient air quality monitoring stations in Amman city was around 38%, in Irbid city around 15%, and Zarqa city around 30% and the average rate of decline in all monitoring stations in the three provinces around 28%. The study also showed that the average rate of decline in the daily rates of PM10 without calculating the impact of dust storms to show the impact of the suspension of most human activities from transportation, industry, and services monitored by the ambient air quality monitoring stations in the city of Amman was around 47%. Whereas, in the city of Irbid around 32%, in Zarqa city around 36%, and the average rate of decline in all monitoring stations in the three provinces around 38% [18].

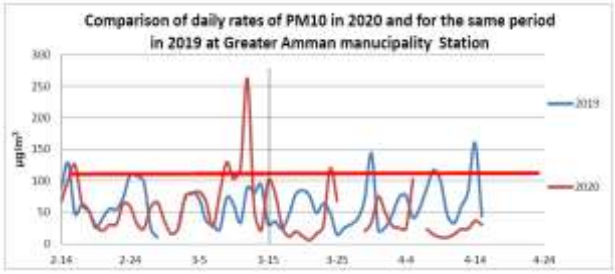

Fig. 2 Example; comparison of daily rates of PM10 in 2020 and for the same period in 2019 at the Greater Amman municipality station.

South Jordan and specifically Ma`an area doesn't have a monitoring station. The red line in the above figure it's the line between the pre-crisis and post-crisis periods. Also, the study showed that the average rate of decline in the daily rates of nitrogen dioxide gas NO_2 due to the discontinuation of most human activities from transportation, industry, and services, which were monitored by the ambient air quality monitoring stations in the city of Amman was around 50%, in the city of Irbid around 71% and Zarqa city around 56% and the average rate of decline in all monitoring stations in the three provinces around 59%.

The average percentage of decline in the daily rates of SO_2 concentrations due to the discontinuation of most human activities from transportation, industry, and services, which was monitored by the ambient air quality monitoring stations in the city of Amman was around 18%, in the city of Irbid around 47% and Zarqa city around 44% and the average rate of decline in all monitoring stations in the three provinces around 37%.

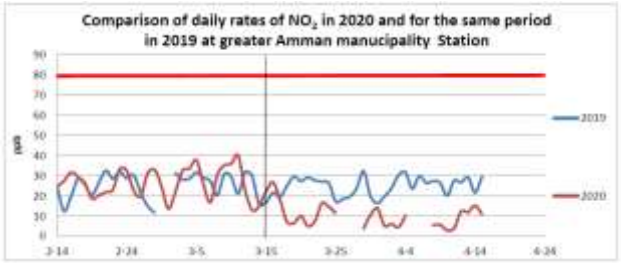

Fig. 3 Example; comparison of daily rates of No2 in 2020 &for the same period in 2019 at the Greater Amman municipality station

The results of the study Table 1 for monitoring the ambient air quality for inhaled fine particles suspended in the air with a diameter of equal or less than 10 microns PM10 (excluding dust storms) as well as all gaseous pollutants were within the allowable limits in Jordanian Standard No. (2006/1140) where no exceeding in daily rates was detected at all monitoring stations [18].

Table 1: The percentage of reduction in pollutant rates in the three major cities [18].

Pollutants	City	Percentage decline in daily rates for 15/3-15/4/2020 compared to 14/2-14/3/2020	Percentage decline in daily rates for 15/3-15/4/2020 compared to the same period in 2019	Average
PM10 (with dust storms effect calculated)	Amman	43.3%	32.7%	38%
	Irbid	16.2%	13.5%	14.8%
	Zarqa	30.7%	29.5%	30.1%
PM10 (without dust storms effect calculated)	Amman	48.2%	46.1%	47.1%
	Irbid	26.7%	36.8%	31.8%
	Zarqa	32.8%	39%	35.9%
NO_2	Amman	51.8%	48%	49.9%
	Irbid	66.7%	75.8%	71.2%
	Zarqa	43.6%	68.4%	56%
SO_2	Amman	24.4%	11.6%	18%
	Irbid	34.6%	60.2%	47.4%
	Zarqa	28.5%	59.5%	44%
CO	Amman	26%	9%	17.5%
	Irbid	8%	55%	31.5%
	Zarqa	48%	35%	41.5%
O_3	Amman	41%	6%	23.5%
	Irbid	17%	25%	21%

2 Relationship Between Air Pollutants and Photovoltaic (PV) Panels Efficiency

Air pollutants include small-(PM10) and fine (PM2.5) particular matter, ozone, NOx, and Sox. The primary sources of these particles are incomplete combustion, automobile emission, dust, and cooking. Air pollutants affect how sunlight passes through the atmosphere, which scattering, and extinction of light reduces the available solar resource and increases the fraction of diffuse light [4, 19, 20].
To investigate this relation many researchers studied the effect of air pollutants on different types of photovoltaic cells, Table 2 shows some studies that focused on the effect of dust and other types of air pollutants on the performance of the solar PV cell.

Table 2: Some studies investigated the effect of air pollutants on solar PV efficiency.

Ref.	Study Location	Type of Air Pollutant	Result
[8]	Nis, Serbia	Dust (any particulate matter diameter of fewer than 500 µm.	Three Modules were used with regard to the type of air pollutant: ➢ The efficiency of the carbon-soiled module was reduced on average by 37.6% as compared to the clean solar module. ➢ The $CaCO_3$ soiled module efficiency was reduced by 6.7%. ➢ The efficiency of the soil particles soiled module was reduced by 6.8%.
[21]	Ahmed abad, India	PM, Dust, Ozone	Global climate modeling (GCM) was used. ➢ Solar energy production is currently reduced by 17−25%. ➢ PM is responsible for~1 GW of solar power reduction.
[22]	Central Greece	Aerosol (dust, PM10)	The analysis and result are based on three integrated methods: • Performance ratio (PR) calculation. • Bilinear models to calculate the PV power generation. • normalized efficiency calculation. ➢ The results show a decrease of 5.6% in PV performance only in high-concentration PM10.
[19]	Delhi	Urban haze (PM2.5)	The analysis and result for the relation between PM2.5 concentration and the loss in solar irradiance received by flat panel silicon PV, using the form of a mono-exponential decay. The study showed that silicon PV panels were reduced by 11.5% ± 1.5% or 200 kWh/m² per year period from 2016 - 2017 due to air pollution.

3 Case Study; Ma`an Development Area (MDA)

Jordan area is exposed to a very high solar irradiance, which has more than 300 sunny days a year, providing a sunshine duration of about 3125 hours/year [23]. Alrwashdeh et al. [24] researcher has divided Jordan into five regions with regard to solar radiation as shown in Fig. 4. The southern region represents the Ma'an and Aqaba area, which has the highest solar isolation in the country and has the lowest values of diffuse irradiance. The annual average daily global irradiance is between 6-7 kWh/m².

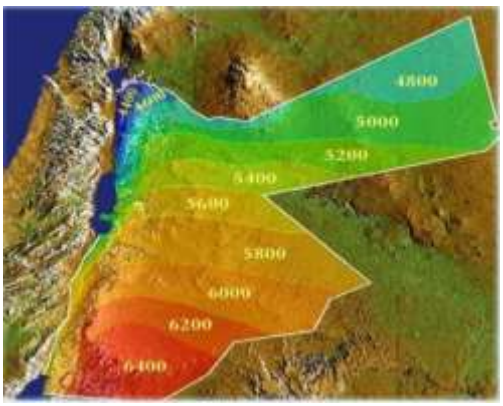

Fig. 4 Global Solar Radiation Map of Jordan in Wh/M²/Day.

Also, Ma`an Area has enjoyed several competitive advantages, such as [25]:

- The Highest Direct Solar Irradiance (DNI) is in the Arabian desert, north Africa, and Arabian Peninsula, where it amounts to 2700 kW/h/m^2/y.
- The Highest Gross Solar Irradiance (GHI) In the Arabian Desert, North Africa, and Arabian Peninsula, as it amounts to 2300 kW/h/m^2/y.
- The flat topography of the land.

Due to these advantages, many projects were established in the Ma`an area, one of these projects being Ma`an Development Area, the data collected in this research from MDA 1028 kWp PV Plant, is as follows:

- Energy (kWh)
- Performance Ratio (PR)
- Irradiation (kWh/m^2)

Monthly Data March, April, and May 2019 and March, April, and May 2020.

Fig. 5 MDA PV plant

The monthly data for March, April, and May 2020 was during COVID-19 Pandemic (Table 3), since the air pollutants concentration decreased in all Jordanian cities due to the comprehensive and partial lockdown for all sectors, am used these data to compare it with the reading after COVID-19 Pandemic for the same period 2019.

Table 3 Monthly Data March, April, and May 2019-2020.

Parameter	March		April		May	
	2019	2020*	2019	2020	2019	2020
Energy (kWh)	175,048	165.46	195,094	183,099	196.299	191,382
Performance ratio	87.30%	87.5%	87.47%	85.9%	86.98%	83.6%
Irradiation (kWh/m^2)	194.7	183.85	217.0	207.4	225.5	226.4

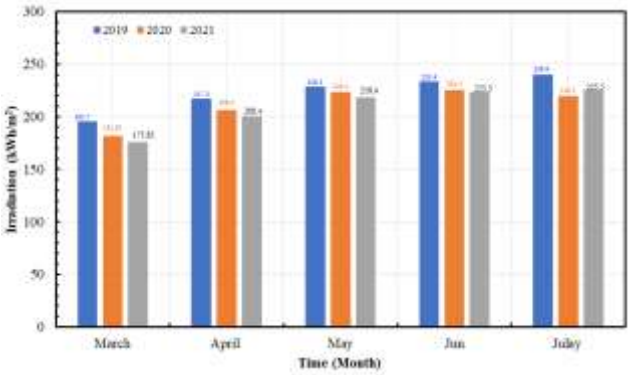

Fig. 6 Comparison of the monthly irradiation rate in 2020, 2021, and the same period in 2019 (Covid-19).

Figure 6 shows the comparison between solar irradiation in 2019, 2020, and 2021. There is a slight decrease in irradiation in May 2020 and 2021 in comparison with May 2019, other months are within the range. On 15 March 2020 region and Jordanian cities witnessed a huge dust storm called "the Dragon Storm ", dust accumulated on the surface of the solar panels, which may be one of the reasons for the significant decrease in irradiation in march 2021 in comparison with 2019. Another reason for the lack of a noticeable change in solar radiation is due to the ambient air quality in the Ma`an area in comparison with Jordanian cities, so reading will observe differences in main cities like Amman, Zarqa, or industrial regions.

4 Conclusion

During the COVID-19 pandemic, Most countries responded by social distancing measures and severely diminished economic and other activities such as transportation, industrial infrastructure, tourism, school, and universities, the energy used by industrial processes and the road transportation sector are responsible for about 54% of the nonmethane volatile organic compounds (NMVOC), 51% of the NOx, 30% of PM2.5 and 25% of SO_x emissions. This response has an impact on humans and the environment, Consequently, the impact on air quality was rapidly visible at various spatial scales, in Jordan for example; the concentration of air pollutants Significantly decrease, And by reference to many studies research I found that inverse relationship between the efficiency solar PV Panels and Air pollutants concentration, when the air pollutants rate increase the performance and energy produced decreased, the solar radiation data collecting from MDA appeared slightly changed in solar radiation rate during and before the pandemic. The authors

suggest doing further investigation for this study by collecting solar radiation data from industrial or Areas with more traffic.

References:

[1] Khaleel I Abass1, Dina S M Al-Zubaidi, Ali A K Al-Waeli, Effect of pollution and dust on PV performance, Vol.3, Issue.4, 2017.

[2] Enas Taha Sayed, Hegazy Rezk, Abdul Ghani Olabi, Mohamed R. Gomaa, Yahia B. Hassan, Shek Mohammod Atiqure Rahman, Sheikh Khaleduzzaman Shah, Mohammad Ali Abdelkareem. Application of artificial intelligence to improve the thermal energy and exergy of nanofluid-based PV thermal/nano-enhanced phase change material. Energies 2022, 15. https://doi.org/10.3390/en15228494

[3] Monther Alsboul, Mohd Sabri Mohd Ghazali, Mohamed R. Gomaa and Aliashim Albani. Experimental and theoretical investigations of temperature and solid volume fraction-dependent thermal conductivity of Erbium oxide/Ethylene Glycol (Er_2O_3/EG) nanofluid for thermal energy applications. Chemical Engineering & Technology 2022. https://doi.org/10.1002/ceat.202200159

[4] Mohammad Shalby, Ahmad Abuseif, Mohamed R. Gomaa, Ahmad Salah, Abdullah Marashli, Hani Al-Rawashdeh. Assessment of Dust Properties in Ma'an Wind Farms in Southern Jordan. Jordan Journal of Mechanical and Industrial Engineering 16 (4), 2022.

[5] Mohamed R. Gomaa, Talib K. Murtadha, Ahmad Abu-jrai, Hegazy Rezk, Moath A. Altarawneh, and Abdullah Marashli. Experimental Investigation on Waste Heat Recovery from a Cement Factory to Enhance Thermoelectric Generation. Sustainability 2022, 14, 10146. https://doi.org/10.3390/su141610146.

[6] Mohamed R. Gomaa, Mohsen Ahmed, Hegazy Rezk. Temperature distribution modelling of PV and cooling water PV/T collectors through thin and thick cooling cross-fined channel box. Energy Reports 8 (2022), 1144-1153. https://doi.org/10.1016/j.egyr.2021.11.061.

[7] Harry Wirth, "Recent Facts about Photovoltaics in Germany", 2020.

[8] Ivana s. radonji, tomislav m. pavlovi, dragoljub lj. mirjani, miodrag k. radovi, dragana d. milosavljevi, and lana s. panti," investigation of the impact of atmospheric pollutants on solar module energy efficiency", Vol. 21, No. 5, 2017.

[9] Hani Al-Rawashdeh, Ahmad O. Hasan, Hazem A. Al-Shakhanbeh, Mujahed Al-Dhaifallah, Mohamed R. Gomaa, and Hegazy Rezk. Investigation of the Effect of Solar Ventilation on the Cabin Temperature of Vehicles Parked under the Sun. Sustainability 2021, 13(24), 13963. https://doi.org/10.3390/su132413963

[10] Mohamed R. Gomaa, Hegazy Rezk. Passive Cooling System for Enhancement the Energy Conversion Efficiency of Thermo-Electric Generator. Energy Reports 6 (2020) 87–692. https://doi.org/10.1016/j.egyr.2020.11.149

[11] Mohamed R. Gomaa, Waleed Hammad, Mujahed Al-Dhaifallah, Hegazy Rezk. Performance enhancement of grid-tied PV system through proposed design cooling techniques: An experimental study and comparative analysis. Solar Energy 2020, 211, 1110–1127. https://doi.org/10.1016/j.solener.2020.10.062.

[12] Marek Jaszczur & Janusz Teneta & KatarzynaStyszko & Qusay Hassan & Paulina Burzyńska & EwelinaMarcinek & Natalia Łopian, "The field experiments and model of the natural dust deposition effects on photovoltaic module efficiency", 2018.

[13] Hani A. Al-Rawashdeh, Mohammad Al-Hwaiti, Amani Yaseen, Mohamed R. Gomaa. Influence of Partial Replacement of Cement by Various Percentage of Scoria in Self-Compacting Concrete on Thermal Conductivity in the Jordan Building Construction. International Review of Mechanical Engineering (2021), 15(7), pp. 385-393. https://doi.org/10.15866/ireme.v15i7.20929.

[14] Mohammed AlJuhani, Mohamed R. Gomaa, Talal S. Mandourah, Mowffaq M. A. Oreijah. The Environmental Effects on the Photovoltaic Panel Power: Jeddah Case Study. Journal of Mechanical Engineering Research and Developments (2021), 44 (6), pp. 251-262. https://jmerd.net/06-2021-251-262/.

[15] Mohamed R. Gomaa, Mujahed Al-Dhaifallah, Ali Alahmer, Hegazy Rezk. Design, Modeling and Experimental Investigation of Active Water Cooling Concentrating Photovoltaic System. Sustainability 2020, 12(13), 5392. https://doi.org/10.3390/su12135392.

[16] Nadia M.T. Jebril, "Impact of the COVID-19 Pandemic on the environment–A case study of Iraq ",2020.

[17] Sorin Cheval, Cristian Mihai Adamescu, Teodoro Georgiadis, Mathew Herrnegger,

Adrian Piticar and David R. Legates, "Observed and Potential Impacts of the COVID-19 Pandemic on the Environment",2020.
[18] Director Environmental Monitoring and Assessment Directorate /ministry of environment, 2020.
[19] I. M. Peters, S. Karthik, L. Haohui, T. Buonassisi, A. Nobre. Urban Haze and Photovoltaics. 2017.
[20] Ramadan J. Mustafa, Mohamed R. Gomaa, Hegazy Rezk. Environmental Impacts on the Performance of Solar Photovoltaic Systems. Sustainability 2020, 12 (2), 608. https://doi.org/10.3390/su12020608.
[21] Mike H. Bergin, Chinmay Ghoroi, Deepa Dixit, James J. Schauer, and Drew T. Shindell, "Large Reductions in Solar Energy Production Due to Dust and Particulate Air Pollution" ,2017.
[22] Elias Roumpakias and Tassos Stamatelos," Surface Dust and Aerosol Eff ects on the Performance of Grid-Connected Photovoltaic Systems",2020.
[23] Ali M Baniyounes. Renewable Energy Potential in Jordan. International Journal of Applied Engineering Research, Vol. 12, Nu. 19 (2017) pp. 8323-8331.
[24] Saad S. Alrwashdeh, Falah M. Alsaraireh, Mohammad A. Saraireh. Solar radiation map of Jordan governorates. 2018.
[25] Ma'an Development Company. https://jo.arabplaces.com/maan/maan-development-company-633440. (Access on September 2022)

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Ahlam. M. Alsaidat, Mohamed R. Gomaa are equal for all work.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself
No sources of funding.