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Effect of pollution and dust on PV performance

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Abstract—*Photovoltaic or PV systems are one of the next generation's renewable energy sources for our world energy demand. It's a method of generating electrical power by converting solar radiation into direct current electricity. When light shines on a PV cell, it may be reflected, absorbed, or pass right through. But only the absorbed light generates electricity. An electrical field is created near the top surface of the cell where these two materials are in contact. The PV system affected highly by the dust and pollutants accumulation on its surface as it reduces the solar light reaches the cell; as a result reduce the cell outcome.*

In this experimental work, three types of Iraqi construction materials (cement, plaster, and borax) were used as pollutants to evaluate their effect on the PV cell performance. The results reveal that borax has the lowest impact on the cell current while plaster has the maximum level. The output power and efficiency were influenced by these impacts and plaster ranked the minimum efficiency with about 25.8% reduction compared to clean cell.

Keywords—Borax, Cement, constructions pollutants, dust, plaster.

I. INTRODUCTION

Recent years have shown the fragility of the world oil situation, with prices fluctuating from above 140 US$ to less than $ 30, causing economic troubles for both oil exporters and importers [1]. If we add to this, burning fossil fuels causes great harm to the environment due to the emitted pollutants from the product of combustion, both in power plants and vehicles [2, 3].

If the suffering of Iraqis from permanent power outages was added to all that, and their need to operate millions of generators working on diesel and gasoline, that cause very high air pollution [4]. The only solution is to reduce dependence on fossil fuels and increase the share of renewable energies from energy production [5]. Iraq has an excellent location as the sun shines for over 340 days a year and strongly medium radiation from 240 W/m^2 in winter to 960 W/m^2 at summer [6].

Photovoltaic is a renewable source of energy, which converts the sunlight directly into electricity without creating any air or water pollution. The heart of photovoltaic system is a solid-stat device called a solar cell [7]. Since the sunlight is endless and very abundant PV cells have very high potential to be a primary source of energy. There are many different types for the photovoltaic, which became more efficient and cheaper with R &D efforts. PV panels are usually placed on the roof of the building. There are many environment factors that can impact the PV efficiency for example humidity [8], industrial waste [9], and air pollution (dust, fossil fuel and grime) [10]. However, the environmental impact of the environmental variables such as temperature, wind, and humidity on the PV outcomes is very high compared to any other renewable or non-renewable electricity system [11]. Many researchers studied the effect of dust on different types of photovoltaic cells and found the effect of dust and pollutants in the studied areas. Table 1 shows some studies that focused on the effect of dust and pollutants on the performance of the solar cell.

Table.1: Some studies investigated the impact of dust accumulation on the PV performance

Ref.	Year	Location	Work conditions	Key findings
Goossens D and Van Kerschaever [D]	1999	Belgium	The impact of wind speed and dust accumulation on the PV cell performance using wind tunnel.	Wind speed affects the PV cell performance largely since the output reduction is greater in high winds than in low winds. At the same time, the wind affects the sedimentological structure of the dust coating on the cell, resulting in a higher transmittance (of light) for coatings created during high winds.
Beheary and Abdel-	2006	Egypt	The dust accumulation impact on the PV systems	The dust accumulation, the panel tilt angle, and the panel orientation with respect to the

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Moneim [E]			performance	dominant wind direction are the main reasons for the reduction in glass normal transmittance. The slope that generated the best data points was 45° angle facing south.
Kaldellis and Kokala [F]	2010	Greece	The performance of five identical pairs of photovoltaic panels mounted on the surface was studied in an urban environment with aggravated contamination.	the presence of dust considerably affects the PV-panels' performance even for a relatively small dust deposition density of (~1 g/m^2) may result in considerable energy loss up to 40 €/kWp on an annual basis.
Beattie et al. [G]	2011	UK	Numerical and analytical models of dust accumulation on PV modules in dry weather was studied and compared to practical investigation of dust accumulation on a surface of glass.	The accumulation process can be described on the basis of the size of the dust particles before the exponential decay, which is the result of particle aggregation.
Mekhilef et al. [Q]	2012	Malaysia	dust, humidity and air velocity have been taken into account simultaneously	Each one of these three factors affect the other Two. The effect of these factors should be taken into consideration in parallel when studying the PV performance..
El-Din et al. [W]	2013	Egypt	The effect of deposition of air born suspends matters on PV cell in harsh climates located close to the sea.	As the dust deposition density increased from 0 to 0.36 mg/cm2, the reduction in the PV efficiency was up to 17.71%. During a testing period of 30 days the average degradation in the efficiency was 9.86%.
Kazem et al. [C]	2014	Iraq	A review about the sources, properties, and reasons of the Iraqi dust storms and their effect on the PV performance	In Iraq, the negative human activities increased desertification and caused an increase in sand and dust storms. The dust and dust storms affect the PV modules performance and reduced the generated energy.
Kazem et al. [B]	2015	Oman	The effect of variable dust properties on the PV yield	From the studied dusts, the dust from Sohar and Saham has the higher negative effect on the performance because of its properties. The moisture content in these dusts caused this negative action.
Chaichan et al. [10]	2015	Iraq	The effect of Iraqi winter outdoor pollution and dust conditions on PV yield	The exposure, even with a short period, to air pollutants deteriorated the PV yield. The polluted and dusty PV panel outcome was declined about 12%, while the naturally cleaned cell (by rain) lost about 8% compared to the clean panel. The use of sodium surfactant or alcohols preserves high rates of the PV panels' performance.
Kazem and Chaaichan [A]	2016	Oman	The dust physical properties of six locations in Oman	64% of the dust particles size ranged from 2 to 63 µm in diameter. There is no significant loss of energy productivity due to the traceability of a little surface of dust (less than 1 g / m^2) on the photovoltaic unit. The daily loss in PV

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				efficiency didn't exceed 0.05%. However, after 3 month exposure to outdoor conditions the efficiency reduced by 30-35%. It is important to clean the PV panels in intervals less than 3 month to reduce the energy loss.
Darwish et al. [R]	2016	Malaysia	A solar simulator was used to investigate the effect of calcium carbonate on a PV module	The different masses of the distributed dust do not affect the open circuit voltage of a PV system, but it impact on the short circuit current are large. The calcium carbonate has a clear and sizable effect on short circuit current and maximum power.

The research listed in the table above shows a clear effect of dust on PV performance. In this study, the effect of accumulation of building materials such as cement, plaster and borax will be tested experimentally on the PV cell performance.

II. EXPERIMENTAL SETUP

The current study experimentally investigates the performance of two identical pairs of photovoltaic (PV) panels, the first being clean and the second being artificially polluted with different, commonly met in urban and other environments air pollutants. The PV-panels under comparison are both operating under the same environmental conditions, being nearby located and adjusted at the same inclination. The effect of pollution deposition on PVs' power output and efficiency is examined, considering also various pollutants' mass depositions on the PV-panels' surfaces. Thee air pollutants which are volatile materials from construction processes that have higher concentrations in cities

(Cement, plaster and borax) were selected to investigate their effect on PV-panels' performance by finding the efficiency of the PV in the case of each one of them. Current and voltage would be measured in this experiment in order to find the power of PV panel, and then efficiency would be calculated using power and area of PV panel by following equations (P = V.I , Efficiency = P/A). Equipment's used in the experiment are as following:

- PV-panel.
- Lead-acid battery storage system.
- DC / DC charge controller (1 kW rated power).
- Electrical loads (lighting).
- Three pollutants (Cement, plaster and borax)

Fig. 1 represents the used instruments in the tests.

Fig.1: A photo of the used instruments in the experiments

Experimental Procedure

Three types of construction materials air pollutants (Cement, plaster and borax) have been used with weights of (2, 4, 6, 8 and 10 grams). Av electrical circuit consist of (control charge, lamp) has been connected PV panel and switch on constant light that located above PV panel. A multi-meter current and voltage was used to measure the clean PV panel first. The tested pollutants were distributed on the surface of PV panel on steps of 2 grams each. The PV current and voltage were measured.

III. RESULTS AND DISCUSSIONS

The influence of constructing materials accumulation on the efficiency of solar PV panels was studied using indoor solar simulator. A constant light radiation condition is used by mean of lamp to overcome the variation that may be experienced under the sunlight. The system of measurements is consists of solar panel of area, voltmeter for measurement of generating voltage and producing current, a suitable load resistance, a charge control. The electrical parameters like voltage and current have been measured to study the effect of environmental air pollutants on PV panels. The effect of air pollutant can be quantified by comparing the efficiency of panel exposed to air pollutant and clean PV panels.

Fig. 2 shows the effect of construction pollutants accumulation on the current of the studied cell. Plaster caused a high reduction in the PV current compared to the

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other pollutants. Also cement accumulation reduced the cell current highly. Borax caused a relatively lower impact on the cell current. These differences in the impact rates of the studied pollutants refer to the substance physical and chemical properties as clarified by refs. [18, 20].

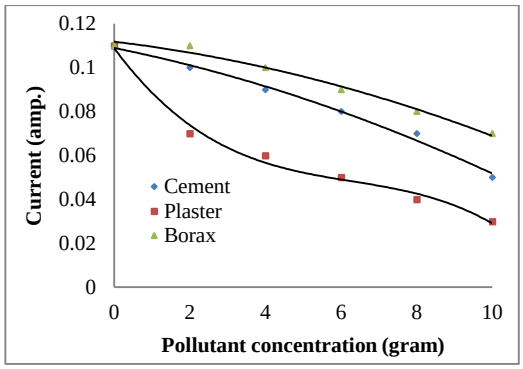

Fig.2: The impact of pollutant accumulation on the PV cell current

Fig. 3 represents the effect of the studied pollutants on the PV cell voltage. The borax affected the cell voltage more than the other pollutants while the cement impact was the lower except when 10 grams were accumulated. The reduction in the cell voltage was relatively limited where the maximum reduction was 0.73%compare with a clean cell voltage.

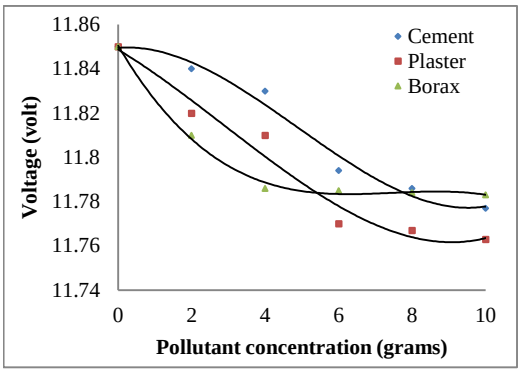

Fig.3: The impact of pollutant accumulation on the PV cell voltage

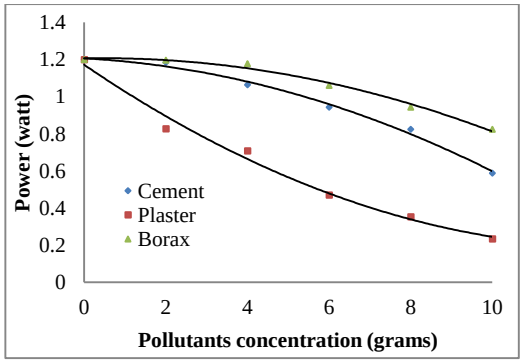

Fig.4: The impact of pollutant accumulation on the PV cell power

Fig. 4 depicts the impact of the studied pollutants on the generated power. Plaster reduced the output power more than the rest pollutants while borax power reduction was the lower one. The cell output power influences by the current and the voltage. The plaster current reduction was high that caused this high reduction in power while the borax current reduction then its power reduced little compared to the other two substances.

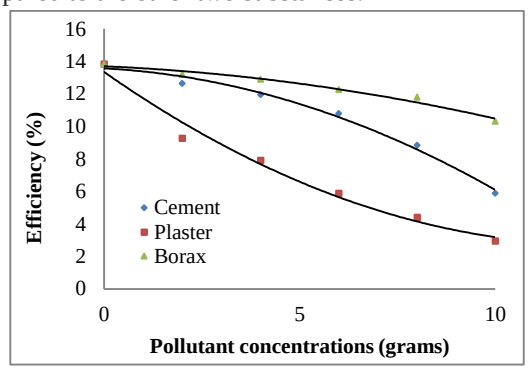

Fig.5: The impact of pollutant accumulation on the PV cell efficiency

Fig. 5 declares the effect of the studied pollutants on the PV cell resulted efficiency. The efficiency curves are similar to the power curves as the cell was subjected to controlled variables (radiation, humidity and air movement). The physical and chemical properties of the tested pollutants have a critical effect on the resulted efficiencies. The results clarify that borax with it low density and small particles size caused the lowers degradation to the PV array outcomes. Plaster has adhesion properties of its molecules causing its aggregation and its accumulation that caused great impact on the PV panels output. Cement affected the cell's I, V, P, and efficiency.

IV. CONCLUSSION

In order for the PV cells to operate at maximum efficiency without energy loss, the panels' surfaces need to be clean and allow free entrance of solar photons. Pollution, dirt, dust and clouds block out the sun and have the same effect on reducing energy generated. The recent experimental study of the effect of three construction pollutants (cement, plaster, and borax) on the parameters of the solar module showed that these parameters are sensitive to the dust and to its accumulation amounts on the panel. The reduction of the performances of the module can be over 25.8% (when plaster was accumulated on the panel with 10grams weight). The tests indicated the significant importance of the PV surface cleaning to improve the economy benefit of the PV power system.

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