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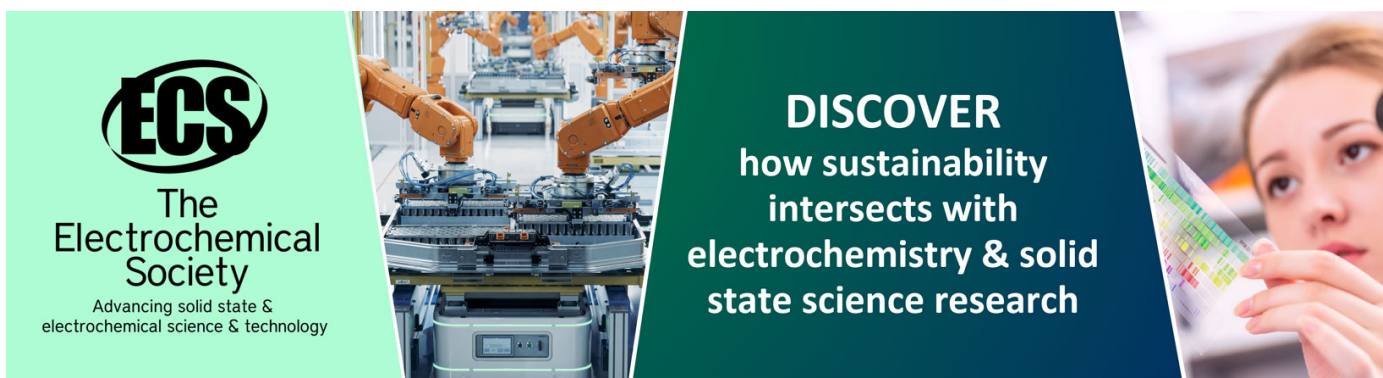
Photovoltaic panel type influence on the performance degradation due dust accumulation

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Photovoltaic panel type influence on the performance degradation due dust accumulation

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Abstract: This study investigates the effect of the type of solar cell technology used on its outcomes degradation when dust accumulates on it. Therefore, in this study, practical tests were performed on the physical properties of accumulated dust in the University of Technology Campus-Iraq for a period of three months. After that, a practical study examined the effect of the type of photovoltaic unit used on the decrease in current, voltage, and energy resulting from the accumulation of this dust with specific mass fractions. The comparison was made between the Amorphous, Monocrystalline, Polycrystalline, and Organic PV modules. The accumulation of dust causes significant decreases in current and has a limited effect on the voltages of all modules studied, as a result, the electric power generated decrease from all the studied photovoltaic modules due to the accumulation of dust. The accumulation of dust had the greatest effect on the Amorphous PV cell, followed by polycrystalline, monocrystalline and finally organic at 42%, 36.3%, 32.9% and 25.7%, respectively. The study demonstrated that the best option is to use monocrystalline cells for the university site. The study also concluded that the choice of any PV technology for a station at any site should be preceded by a study of the effect of dust in that location in order to favor any technique that must be applied.

Keywords: Dust accumulation; Amorphous, polycrystalline, monocrystalline; organic; PV module

1. Introduction

The era of the use of photovoltaic cells has begun to emerge, as the use of this technology has expanded dramatically and its contribution to globally generated electricity reached more than 59 gigawatts for 2015 [1]. Because of its location in the Middle East, Iraq has a high solar radiation intensity [2]. This location near the solar belt gives enough radiation to generate electricity effectively from the PV units [3]. Perhaps, the reason for the failure of Iraq to use the photovoltaic modules is the fact that this country is one of the main natural gas and oil producing countries in the world. Therefore, the electricity production from fossil fuels is considered cheap and cannot be competitive. Also, Iraq climate is characterized by high ambient air temperatures most of the year, and the levels of dust and pollutants there are high [4]. The fact that Iraq was exposed to two decades of severe drought caused large areas of it to turn into deserts and became a source of dust for its neighbors [5]. Scientific research in identifying and encircling the problem of the dust deposition effect on the of photovoltaic modules' behavior is continuing, and scientific publications are still searching for advanced solutions to facilitate the transition from reliance on fossil fuels to dependence on solar applications, especially photovoltaics [6].

Flying and suspended dust in air creates a shadow that impedes the penetration of sunlight and reduces the intensity of radiation reaching the PV modules' surfaces [7]. Also, the dust cumulating on the surface of these cells prevents the passage of rays into the cells, and this results in the process of heating parts of the cell resulting in significant reduction in photovoltaic modules outcomes [8]. Studies have unanimously agreed that the accumulation of dust and pollutants causes the deterioration



of the electricity produced by the PV module [9, 10 & 11]. There are many factors that determine the dust accumulation rate on the surfaces, including concentrations of dust particles suspended in the air, the angle of inclination of the cell, and conditions of the air region such as humidity, and wind speed [12].

Ref. [13] tested the influence of the dust precipitated particles' size on cumulating rate in Doha, Qatar. The authors revealed that increasing the exposure time to dust increases the rate of dust accumulation, to reach a certain limit, after which this rate is stable if the solar panel is exposed to dust for long times. Ref. [14] indicated that the physicochemical properties of the dust clearly affect the distribution of dust accumulated on the PV panels surface and cause degradation to the power produced from them. As explained by Ref. [15], fine particles of dust cause more reduction in electricity to be generated than if the dust particles are of large sizes. Fine dust is distributed over a larger surface area in a better order than coarse dust particles, resulting in a decrease in clean areas and their distribution. The weather conditions of the region where the photovoltaic station is installed cause a direct impact on its productivity, for example the effect of relative humidity is positive, as the mass of water vapor in the air absorbs some solar radiation, causing a decrease in the temperature of the PV module, which results in generated electrical power to be increased [16]. Wind and its speed have an important effect on the accumulated dust. The movement of air causes removal of an important part of dust cumulated on the PV panels' surfaces when these surfaces facing the movement of air. When the surface of the panel does not encounter air movement, the accumulation of dust will increase [17].

The amount and density of dust cumulated on the PV panel's surface affect its productivity, also the degradation of this productivity is clearly influenced also by the physical and chemical dust properties and its components that differ from one region to another [18]. In dry deserts the main component of dust is silica. In large cities, the sources vary as smoke from the exhausts of cars, coal-fired ovens, chimneys, etc. [19]. In agricultural areas, most of the dust flying is composed of soil [20]. Dust usually blows in the arid and semi-arid regions, and is produced in these areas as a result of dry soil and lack of rain. There is also a relationship between the impurities that make up the dust and the seasons of the year. For example, from these impurities the pollen that increases in spring season, soot and smoke, bird droppings, constructing materials, etc. [21]. A large part of pollution in Baghdad-Iraq is due to heavy traffic as well as to the atmospheric suspended dust [22].

Many researchers studied the impact of dust physical properties on PV performance [23-27]. The researchers have unanimously agreed that dust and pollution are a serious problem affecting the performance of photovoltaic cells, especially in desert areas where there are conditions of solar radiation that are optimal. Some researchers, such as the Ref. [28] who studied the effect of artificial dust (talc and clay) on the efficiency of the PV unit. Ref. [29] also studied the effect of five types of artificial dust (sand, silica, ash, calcium carbonate, and red soil) on the performance of PV modules. The study concluded that the accumulation of these substances directly affects the cell voltage generated and this deterioration ranges from 4 to 24%.

The researchers focused more attention on the effect of the dust accumulated on the PV module surface and neglected the influence of the type of this surface. Since there are many types of photoelectric cells and their components, the surface type of the photoelectric module certainly plays an important role in determining the effect of accumulated dust on the performance and efficiency of the module.

Among the most important types of photovoltaics and the most widespread there are four silicon types, including: Amorphous PV Panels, which is a type of photovoltaic cells that is made of thin layers deposited on sheets of stainless steel or plastic. It is useful for use in applications that do not require high energy such as pocket computers and watches. Currently, after the spread of the technique of stacking several layers on top of each other, it is possible to produce a higher electrical power [30]. Monocrystalline PV modules are another type of photovoltaic cells. It consists of monocrystalline cells made from a cylindrical silicon alloy with high purity, and cut this alloy to many chips to form the solar cells. Because this type of cell is made of silicon, it has the highest efficiency rates ranging from 15-20% [31]. Another type of PV cells is Polycrystalline panels, which are formed by mixing multiple crystals from multiple silicone sources. These cells are just less efficient than monocrystalline cells, and also cost less [32]. The fourth type of solar cell is an organic solar cell, made of carbon and organic electronics instead of silicon. The organic cell contains two layers of semiconductors made of plastic polymers and other flexible materials. These cells absorb light, which causes the exciton to

divide, allowing the electron to liberate and move to a hole created by another absorbing photon, thereby generating electricity [33].

In this study, a comparison will be made between the energy produced for each of the above PV types when the panels are clean. Next, the productivity of these PV units will be compared when Iraqi dust accumulates by a specific mass part. Dust is collected from the weather of Baghdad - Iraq (University of Technology campus). The type of dust in the chosen location studied by Ref. [27], who investigated its effect on monocrystalline PV cells. In this study, its negative effects will be studied on four types of PV cells to choose the best ones to be installed in this campus. The most important point in this study is to show that every site, even within a single city, may need to install a PV system of a type that differs from the other site within the same city due to its surrounding conditions.

2. Experimental Setup

A horizontal glass panel was used to collect dust for the period from August to the first of December 2019, which represents the Iraqi autumn and the first part of winter season. The dust sample collected in the University of Technology Campus, which is surrounded by a renewed residential area from the south, a large industrial area from the north side, a fast-packed highway street from the west, and a commercial area with heavy traffic from the east [34]. The collected dust was checked using X-ray diffraction (XRD) (the used device is Bruker D8 Advance) and X-ray Fluorescence (XRF) (the used device is Horiba XGT-7200) to analyze the dust components, in terms of quantity and quantity. Figure 1 illustrates XRF results.

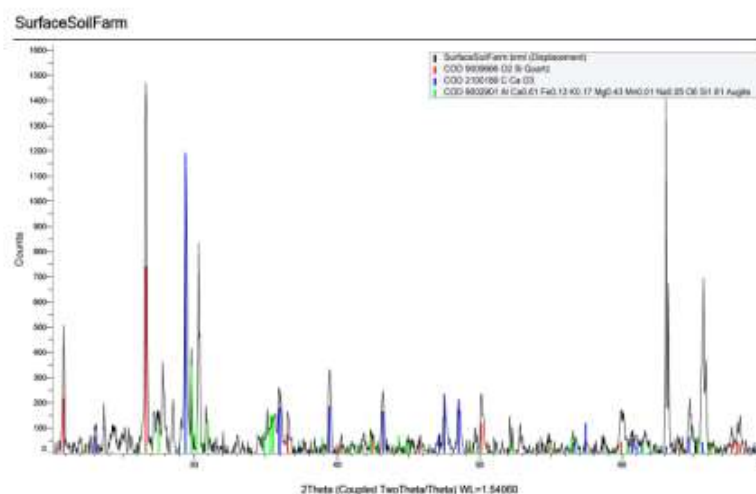


Fig. 1. XRD patterns of collected dust

The current study was divided into two phases:

In the first phase, dust was collected for three months, and this dust was subjected to several tests to define its physical specifications. These tests were:

2.1. Specific gravity

Specific gravity: This characteristic determines whether the examined substance is heavier or lighter than water and symbolized by the symbol (Gs). Gs expresses the ratio between a volume of the material examined to an equal volume of water. This examination was performed according to BS 1377-2: 1990: 9.3 [35].

2.2. Geometrical content

The mineral content in the collected dust is checked using Moh's Hardness Test, where the scratch resistance of the collected dust was compared with ten reference metals having known hardness.

2.3. Moisture content, liquid limit, and plastic limit

In testing the moisture content, the moisture content in the dust is evaluated, which represents the limit of the liquid (moisture) borne by the dust, after which the dust becomes a plastic. So, the range of moisture content that should not exceed the liquid limit is the plastic limit. The plastic state of the dust

and expresses the difference between the liquid and plastic limits. The plastic limit is located in an area between the plastic and semi-solid states. All these tests are done by testing the moisture content.

2.4. Grain size analysis

An analysis of the grain size of the dust collected with sieves and hydrometer was performed, and this examination can be made for small sizes till 63 microns. As shown in Table 1 (group of sieves listed according to the sequence of their sizes). Since part of the suspended dust in air is originally from deserts, so the size of these particles is less than 50 micrometers, so a hydrometer scale was adopted to test the sizes of the dust particles studied, which crossed from a 50-micrometer sieve. Measurements of the dust particles size, whether through sieves or the hydrometer scale, was conducted according to BS 1377-2: 1990: 9.3 [36].

Table 1, the used sieves sizes

Sr. No.	Sieve No.	Sieve Size
1	5	3.15 mm
2	7	2.15 mm
3	9	1.96 mm
4	27	630 micron
5	36	450 micron
6	45	310 micron
7	72	220 micron
8	99	160 micron
9	198	80 micron
10	243	70 micron
11	264	62 micron
12	270	50 micron

In the second tests phase: The collected dust was spread on four PV panels (Amorphous, monocrystalline, polycrystalline, and organic) in a homogeneous manner and with specific mass fractions to study the effect of this accumulation on the performance of each of the used PV panels. The specifications of the photovoltaic modules used in the experiments are listed in Table 2. The photovoltaic modules are connected to a monitoring cable and are installed on the roof of the Energy and Renewable Energies Technology Center at the University of Technology - Iraq. The panels are fixed at a 0° to prevent the dust from flying due air movements during the experiment period while the tilt and suit the city of Baghdad is 34°, as Baghdad city located at latitude 33° 34'N and longitude 44° 40'E [37].

Table 2, the tested PV panels specifications

Measures	Amorphous	Monocrystalline	Polycrystalline	Organic
P_{max}	8	13 W	9.35	500 mW
V_{mp}	6 V	12 V	11 V	4.7 V
I_{mp}	0.83 A	1.09 A	0.85 A	106 mA
V_{oc}	8 V	13.8 V	11 V	6.5 V
I_{sc}	200 mA	1.17 A	1.1 A	170 m A
Maximum system voltage	15 V	60 V	40 V	8 V
Size	520*230*22mm	520*230*22mm	520*230*22mm	520*230*22 mm

The tests can be summarized as: After collecting dust from the glass plate daily for a period of three months, as mentioned previously, part of it is taken for the above-mentioned physical tests and the second part is divided into equal mass fractions and placed in plastic bags to preserve it. The PV panels are attached to the south facing the sun. Shiny with low wind speed days were selected to conduct experiments. Each test was repeated three times to ensure repeatability. It was ensured that all photovoltaic units were subject to the same weather conditions (solar radiation intensity, temperature,

humidity and wind speed) during tests examining the effect of dust on its performance. The first experiments were done using clean cells and took the initial values of current, voltage and power. In the following experiments, dust was added at specific weight ratios and the PV parameters were examined. The solar panels are cleaned after the experiment is completed. Since the photovoltaic panels used have equal dimensions but they differ in their performance and output according to the technology used, the degradation rate resulting from dust pollution of cells was chosen as a comparison criterion as follows:

$$\text{Current degradation rate: } I_{\text{dusty}} / I_{\text{clean}} \quad (1)$$

$$\text{Voltage degradation rate: } V_{\text{dusty}} / V_{\text{clean}} \quad (2)$$

$$\text{Power degradation rate: } P_{\text{dusty}} / P_{\text{clean}} \quad (3)$$

I_{dusty} , V_{dusty} and P_{dusty} represent the current, voltage and power generated by the dusty PV modules while I_{clean} , V_{clean} and P_{clean} are the generated parameters of clean modules.

Through all tests, the PV modules outcome were measured and compared to select the optimum PV type for the University of Technology Campos site.

3. Results and Discussion

3.1. Phase 1 (the dust physical properties)

The most important thing that affects the physical properties of dust is its components, which gives it these properties. Figure 2 shows the total dust components: Al_2O_3 , SiO_2 , MgO , K_2O , Cr_2O_3 , SiO_3 , MnO_2 , SrO , TiO_2 , Fe_2O_3 , NiO , P_2O_3 , and Cl are due to industrial processes in the university workshops and the surrounding industrial area, and their quantities are low and limited. there is also CaO in dust, which is expected to volatilize from the construction sites, as these materials are not stored and preserved well. The calcium oxide (CaO) percentage in dust was 7% which is high compared to the rest of the above mineral substances. Silicon dioxide (SiO_2) from desert dust blowing from the Anbar desert in western Iraq contributes a major rate of 54.5%. The most blowing wind on Baghdad is northwesterly wind, which transports the desert dust flying to the city of Baghdad, and because this dust is soft and fragmented, and the sizes of particles are very small, it remains suspended in the air for long periods. From a review of the research that worked in Baghdad and the most recent reference [37], it is noted that the proportions of the components change, but the general trend has the same and this change in the proportions of the components depends on the measurement period and its duration. The results showed that the particulate matters (PM) have 11.86% which is a high percentage and their presence is caused by very heavy traffic in the study area in addition to the presence of dozens of diesel generators that work for long periods to compensate for the lack of electricity supplies and emit hundreds of tons of pollutants to the atmosphere. Also, the percentage of agricultural soil (14.73%) with a high moisture content ratio has a great ability to adhere to surfaces, and its impact on the properties of dust is great. This soil is produced from the fertile lands and farms surrounding Baghdad from the north and south. We must not forget that the city of Baghdad mediates the fertile crescent.

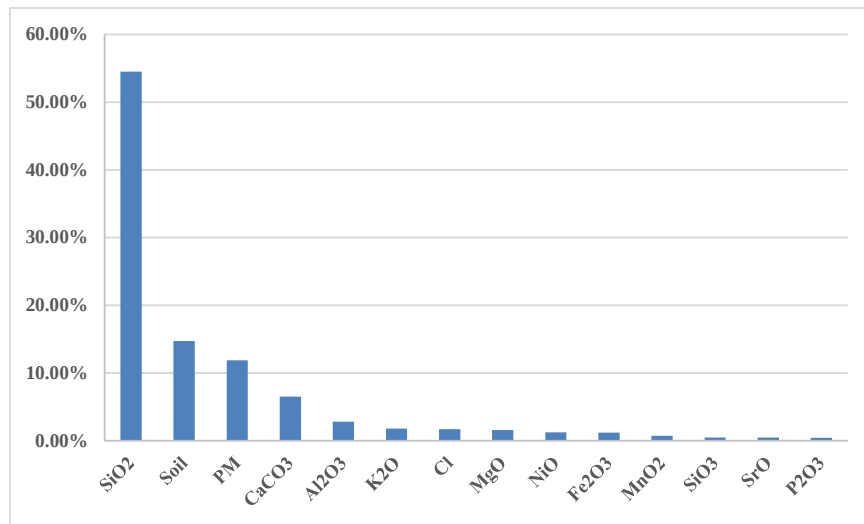


Fig. 2: Natural dust component mass fractions

The division of its density by the water density is defined as the specific gravity of the material. This feature mainly depends on dust components from metals. It determines the way in which these substances accumulate and conglomerate. Since the collection and aggregation of dust particles on the surfaces of photovoltaic modules directly affects the performance of the system, the specific gravity of the dust is of particular importance. Table 3 shows the results of dusts' specific gravity tests. The specific gravity value of Baghdad dust is 2.2, which is not low and means that the dust accumulated on the PV panels cannot be removed by the movement of air but by using cleaning methods. This result shows that Baghdad dust causes a decrease in the performance of the PV system.

Table 3: Specific gravity test results for the studied dust

No.	# of gas jar	Wight of gas jar (m ₁)	Wight of gas jar with water (m ₄)	Wight of gas jar + soil (m ₂)	Wight of gas jar +soil+ water (m ₃)	Ps = (m ₂ – m ₁) / (m ₄ – m ₁) – (m ₃ – m ₂)
1	545	31.220	80.896	56.021	94.041	2.13
2	315	17.969	42.672	28.720	49.041	2.45
3	48	16.534	41.059	26.607	46.242	2.06

Tables 4 and 5 list the results of the liquid limit and the plastic limit checked for collected dust. The results reveal that the moisture content for the studied dust is 31.41% while the Plasticity index (PI) is 24.25 and the dust plasticity is high representing high adhesion on the surfaces it participates on. The moisture content and liquid limit tests determine the water content that represents the limit above which the soil is converted to plastic. While the plastic limit determines that the moisture crossed the liquid limit and entered the plastic limit. These tests show the plasticity index and the plastic state of dust and it was high for the tested dust.

Table 4: Liquid limit test results for the studied dust

Determination No.	1	2	3
Number of drops	12	37	63
Can No.	A-1	A-2	A-3
Mass of can+ moist soil M (cws)	49.6	46.6	100
Mass of can + dry soil M (cs)	49	45	78
Mass of can Mc	46	41	76
M(w)= M (cws)-M (cs)	0.1	2.6	1
Ms=M (cs)-Mc	3	4	1

$W = (M(w)/M_s) * 100\%$	6.5%	8.88%	1.3%
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Table 5: Plastic limit test results for the studied dust

Can No.	A-4	A-5
Mass of can+ moist soil M (cws)	55.1	59.2
Mass of can + dry soil M (cs)	54	58
Mass of can Mc	50	54
$M(w) = M(cws) - M(cs)$	1.1	1.2
$M_s = M(cs) - M_c$	4	4
$W = (M(w)/M_s) * 100\%$	27.5%	30%
Plastic limit %	28.75%	

The following equation defines the Plasticity index:

Plasticity index (PI) = liquid limit (LL) - plastic limit (PL)

(4)

$PI = LL - PL = 53 - 28.75 = 24.25$

The plastisty is high

Table 6 lists the results of the examined dust particles' size. The tests were done to analyze the hardness of the dust particles had a result of less than one, and the size of the dust particles tests indicated bad gradation. This means that the studied dust is smooth, not hard, and very fine depending on the bulk of it being silica oxide, soil and PM. The hardness of any substance is defined as the resistance of this material for penetration by another material. Aggregate resistance is determined by the hardness of individual or contiguous particles, so the dust particles that are expressed as fine are those whose most contents are minerals of low hardness. Fine particles of dust do not cause danger to the surface of the photovoltaic module, as they will not cause harmful cracks in the photovoltaic cells, which means that the establishment of high-capacity PV stations is an acceptable and realistic option since the problems of dust accumulation will be limited by cleaning operations.

Table 6: Dust grain size test results for the studied dust

Sieve (mm)	Mass retained (g)	% retained	% passing
3.350	0	0.0	100.0
2.360	0	0.0	100.0
2.000	0	0.0	100.0
1.190	0	0.0	100.0
0.600	0	0.0	100.0
0.425	125	25.0	75.0
0.300	196	39.2	35.8
0.212	60	12.0	23.8
0.150	55	11.0	12.8
0.075	45	9.0	3.8
0.063	10	2.0	1.8
pan	9	1.8	0.0
Hydrometer test			
Scale	Mass retrained	% retrained	% passing
0.026	7.8	13.333	86.66
0.018	6.4	17.9	82
0.006	5.87	8.2	9.17
0.002	4.38	25.89	74.1
913 nm	2.66	39.2	60.1
756 nm	1.73	34.96	65.04
120 nm	0.68	60.7	39.3
56 nm	0	0	0

In the second part of the study, the effect of adding dust in equal mass to area ratio to four different photovoltaic cells will be analyzed to assess the effect of these additions on the cell output. The study aims to determine the best PV techniques that can work in the atmosphere of the studied site with the least degradation resulting from the accumulation of dust. Dust was added in gm/m^2 on the surface of the cells and shaken for 10 minutes to ensure uniform distribution of dust on them and then exposure to sunlight for the period from 11 AM to 2 PM (peak irradiance period) and measuring the cell output (current, voltage, and power). Before each test the clean panel was loaded with the required mass fraction and it was vibrated using Gemmy Orbit Shaker type VRN-480 to confirm the even distribution of dust on the panel's face. Since the solar modules used in experiments are of equal dimensions but with different outputs, it has been found that using the degradation rate for each variable due to dust accumulation is a reasonable comparison measure. As the experiments were outdoor, then each test took on day. The tests were conducted in a clear sky.

Fig. 3 shows the studied PV modules currents' degradation rate with variable mass fractions. For low mass fractions (5 and 10 gm/m^2) the degradation rate didn't exceed 5% of the generated current for all the studied modules. However, after these mass fractions, the degradation rate increased for all modules but in a variable manner. The current degraded in Amorphous and polycrystalline more than in the monocrystalline and organic cases. At 30 gm/m^2 , the current degradation rates were 38.8%, 31.3%, 34% and 25.2% for Amorphous, monocrystalline, polycrystalline and organic, respectively. The impact of dust accumulation on PV modules is obvious and high, but the variable degradation rates between the modules' current gives an indication. One of the main reasons for the decline and degradation of the solar cell's output due to dust is that it works like a shadow that reduces the solar radiation reaching the cell [38]. However, this matter was neutralized during the experiments, as sunny days and a dustless atmosphere were selected for the experiments. Another reason is the dust sticking to the surface of the cell and preventing the passage of sunlight, as in our case. However, although homogeneous dust distribution is guaranteed across the surface of all cells, the resulting current degradation rate has varied. The reason is in the technology used in the solar unit, which may be more sensitive to dust than others, or in the quality of accumulated dust and here we mean the dust components, which has a fundamental role in the sensitivity of the PV module to its accumulation. The site dust contains high percentage of PM, which has nano size and dark black color and encourage solar radiation absorbance by the dust.

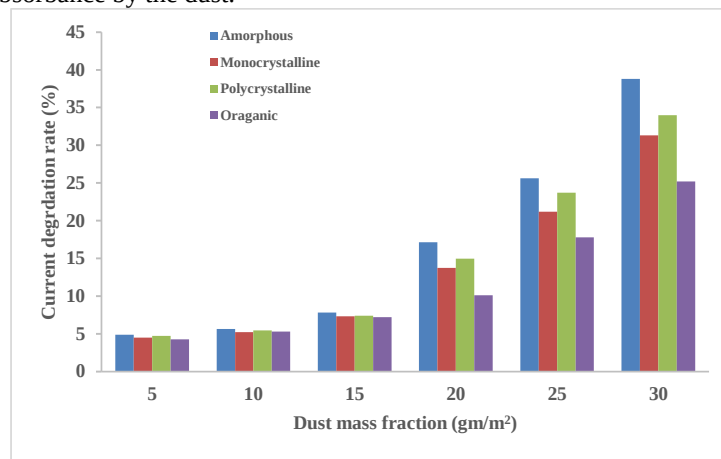


Fig. 3: The studied modules' current degradation rates due dust accumulated by variable mass fractions

Figure 4 represents the studied PV modules' voltage degradation rate because of dust accumulated in variable mass fractions. The impact of accumulated dust can be considered small compared to its effect on modules current. This result corresponds to what was explained by Ref. [18]. In this case, the voltage degradation rates when 30 gm/m^2 were settled on the modules surfaces were 5.8%, 5.3%, 5.4, and 5.2 for Amorphous, monocrystalline, polycrystalline and organic, respectively. At low mass fractions (5, 10 and 15 gm/m^2) the Amorphous module voltage was the most affected, but at high mass

fractions, the precedence was for the polycrystalline. At all used mass fractions, the organic module degradation rate whether for voltage or current were the lowest.

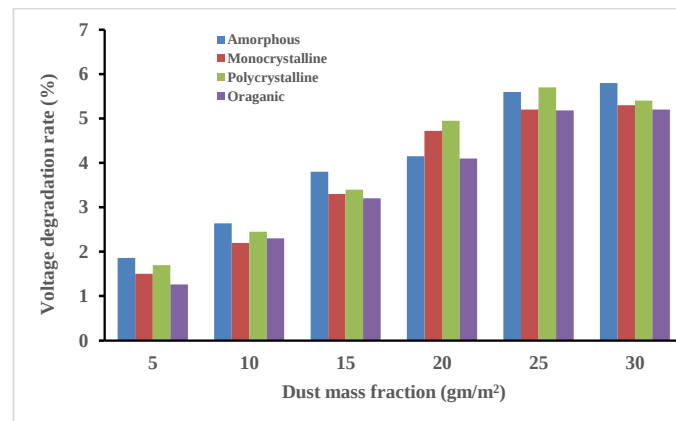


Fig. 4: The studied modules' voltage degradation rates due dust accumulated by variable mass fractions

Figure 5 indicates that the Amorphous PV modules are the worst to be used in the studied site (University of Technology—Iraq campus) as its power degraded due dust accumulation more than the rest studied technologies. The polycrystalline module also affected highly by the used dust accumulation, which means that both Amorphous and polycrystalline techniques are not suitable for the study site. Monocrystalline and organic modules indicated less sensitivity for the dust accumulation and they are preferable for use in this site. However, the organic PV modules has lower outcomes compared with monocrystalline one at the same panel dimension. This type of PV cell deals with electronics made from organic polymers [19]. Solar cells of this type have the advantage of low production costs and flexibility [20]. In the same time, the monocrystalline technology can be considered the most suitable for operation in the University of Technology campus as it bears the accumulated dust in this area better than the rest of the studied techniques. The dust of Baghdad is mostly silica (coming from the Anbar desert bordering the city of Baghdad from the west), and most of this silica is of small measurements, which means greater distribution and spread on the PV panel's surface [15].

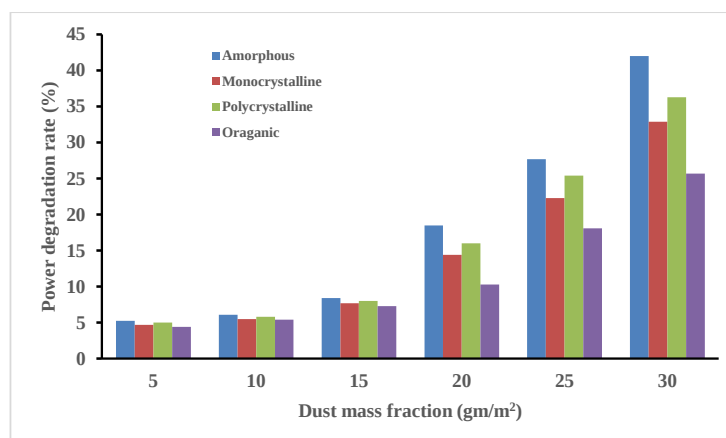


Fig. 5: The studied modules' power degradation rates due dust accumulated by variable mass fractions

Conclusions

The dust accumulation causes a decline in the photovoltaic cells produced power. The researchers have been interested in studying this harmful effect of dust by analyzing the type of dust, its components, weather conditions, and the PV tilt angle and others. In this study, the physical properties of accumulated dust in the University of Technology camp has been examined, and the effect of this dust on four different technologies of photovoltaic modules: Amorphous, monocrystalline, polycrystalline and organic. The studied dust's physical properties are: the specific gravity, dust components types, hardness, and moisture content. Dust samples were collected over three months. In the second part of tests, different amounts of collected dust were loaded and distributed uniformly on the PV module and studied the effect of dust accumulation on the current, voltage and energy produced. Tests have shown that the studied dust has a medium level moisture content and therefore may cause relatively greater damage to the performance of the PV panels compared to other sites' dust. The studied dust has high levels of PM and agriculture soil, which sticks to the surface of the PV panel, so it is difficult to clean.

Significant degradation in the current generated by all studied cells occurs due to the accumulation of dust, but the rate of degradation varies from one technique to another. The decrease in current and power of the Amorphous unit was higher than all other technologies, especially at a mass fractions above 15 g/m², followed by polycrystalline, monocrystalline and finally organic at the lowest degradation rate due to dust deposition. The dust impact on the voltage of the modules studied was relatively low as the largest degradation rate was 5.8% for Amorphous module with 30 gm/m² of accumulated dust mass fraction. The results of the study show that the Amorphous PV technique is the worst that can be used in the University of Technology Campus because of its high power degradation rate and the best is the organic photovoltaic technology. However, since this type of cell produces the least power when the modules dimensions are equal, the study concluded that monocrystalline cells are the best technique that can be used in the studied site. The most important result is that each site (even in the same city) conditions must be studied separately, especially the effect of accumulated dust on it, before advising to construct the station consisting of a specific PV technology.

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