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# Effect of dust pollutant type on photovoltaic performance

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ABSTRACT

Many environmental parameters affect the production of photovoltaic (PV) systems and dust could be one of the main reasons of degradation of PV panels. PV systems utilized in large and small scales accumulate different types of dust which reduce the efficiency. The dust contents, which represent a mixture of different pollutants, are specified by the geographical site. There are many studies focused on the effect of dust on PV performance but few studies have investigated the effect of dust pollutant type on the performance. Mainly, the effect of pollutant type has been investigated indoors and few outdoors. In the present paper the effects of pollutant types on the PV performance have been revised and experimented. A critical review and challenging questions have been developed for the researchers working in this field.



**Contents**



## 1. Introduction

Due to the fast development in economical and technological aspects, solar photovoltaic PV industry has been disbursed globally. As a result of this development, the consumption of energy is increasing dramatically yearly because of development, demand of comfort and the growth of the world population [1]. Electricity is mainly generated by the use of a variety of sources such as fossil fuels which play a vital role in meeting the demand for energy. The impact of greenhouse gases (GHG) on the environment and global warming is enormous and arduous on the people. A suitable solution to reduce these effects and save the environment is the use of solar PV as a renewable energy source.

In a PV, the sun light energy is absorbed by the semiconductors as photons after which they are converted into a voltage. The design of these solar-energy systems covers a set of wide-ranging materials science and engineering, as well as innovative approaches to lowering cost and increasing system performance [2]. In 1960, researchers conducted experiments on semiconductors (III–V and VI) while a new technology for polycrystalline Si (pc-Si) and thin film solar cell was established in order to lower the materials cost and energy input but increase the production capacity.

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In addition to the investment of money and time in the development of materials used in the production of solar cells, there are many factors which need to be investigated and understood. For example dust pollutant types need to be investigated as they have not been studied intensively. Dust is defined as any particulate matter less than 500 μm in diameter, which enters the atmosphere from different sources such as dust lifted by wind, vehicular exhaust, volcanic eruptions and air pollution. Dust may contain small amounts of pollen and also fungi, bacteria, vegetation, microfibers, and, most commonly, organic minerals such as sand, clay, and eroded limestone [3].

The dust pollution effect strongly depends on the local area where the PV system is mounted, so it is difficult to apply a general model in all cases [4].In urban and other environments many types of pollution emitted from different sources can be faced. For example limestone is formed from precipitation of calcium carbonate ($CaCO_3$), ash is emitted from vehicular exhaust while red soil is moved from African deserts. Monto and Rohit have revised the effect of dust on PV performance based on two time periods: 1940–1990 and 1990–2010, and the authors have discussed the effect dust properties based on three main points: effect of dust properties, effect of PV system parameters and effects of environmental parameters [5–7]. A comprehensive review of dust effect on the use of solar systems was presented by Travis Sarver et al. [2]. This research aims to characterize the deposition of dust (pollutant type) and their effect on PV system performance. It is worth mentioning that pollution deposition is a difficult phenomenon influenced by diverse site-specific environments and weather conditions. In this paper the effect of dust pollutant type has been revised. The effect of different pollutant types on current, voltage, power and efficiency has been discussed. Finally, a comparison between different pollutants in term of effect on PV current, voltage, efficiency, power, etc. is presented.

## 2. Position of dust-pollutant type problem

Dust pollution is composed of small solid particles carried by the air currents. These particles are formed by a variety of ways, such as breakage of the solids into small pieces, by means of milling or other ways. The Mine Safety and Health Administration (MSHA) has defined dust as finely divided solids that are in air from the initial state, without chemical or physical changes other than fracture. Dust particle size is generally measured in micrometers. The thickness of dust on the solar panel increases with time [8].

The effect of dust on PV performance is investigated by many studies. The factors which determine the dust accumulation characteristics of PV systems are the materials properties and the local environment [9–13]. The environment consists of the local site-specific factors which are influenced by the natural human activities, built environment characteristics (surface finish, orientation and the installation height), ecological factors and the weather conditions [5].

The properties of dust, which include chemical, biological, electrostatic, shape, size and weight, are very important in its accumulation. Although the PV energy lost due to dust pollution is of great interest to PV system owners and operators, there are few studies presented concerning the dust pollutant types. Much of the information available is valid only to the specific location in which the testing was conducted. For example in Greece many experiments were conducted by Kaldellis to evaluate the effect of different pollutions (ash, calcium carbonate, red soil) on PV performance [14,15] while Hussein used the same pollution but added sand and silica [16,17]. On the other hand in the analysis of dust sand collected from module surface in the United States and the MENA regions in Egypt, it was found that the major components are quartz silicates ($SiO_2$), about 75%; and feldspars ($NaAlSi_3O_8$, $CaAlSi_3O_8$, $KAlSi_3O_3$), about 20% [2,18]. Fig. 1 shows the result of X-ray diffraction (XRD) analysis to identify the chemical composition of dust layers where it is found that the major elements are silicon from desert sand (quartz, or silicon dioxide, SiO2) and calcium from the mineral calcite (calcium carbonate, $CaCO_3$): minor elements included iron, potassium, aluminum, and sodium.

The largest global source of atmospherically transported desert is in North African countries. Sarah conducted an extensive study about dust deposition for 1 year in different zones across Libya. It was found that Libya has the highest deposition rate in North Africa. The mineral composition of sediment collected includes halite (NaCl), chlorite ($MgFeAl_2(OH)$), calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), feldspar ($KAlSiO_3O_8$), quartz ($SiO_2$), and albite ($NaAlSi_3O_8$) [19].

The effect of air pollution is serious in urban areas due to the high population density and growth in the industrial activities [20], specifically dust and particles which are produced by the combustion of fossil fuels and construction activities. Deposition in the front of the PV panels can significantly reduce the amount of solar energy eventually absorbed by the PV. Therefore, an important change in PV panels' output voltage and current is expected due to the PV's remarkable performance degradation.

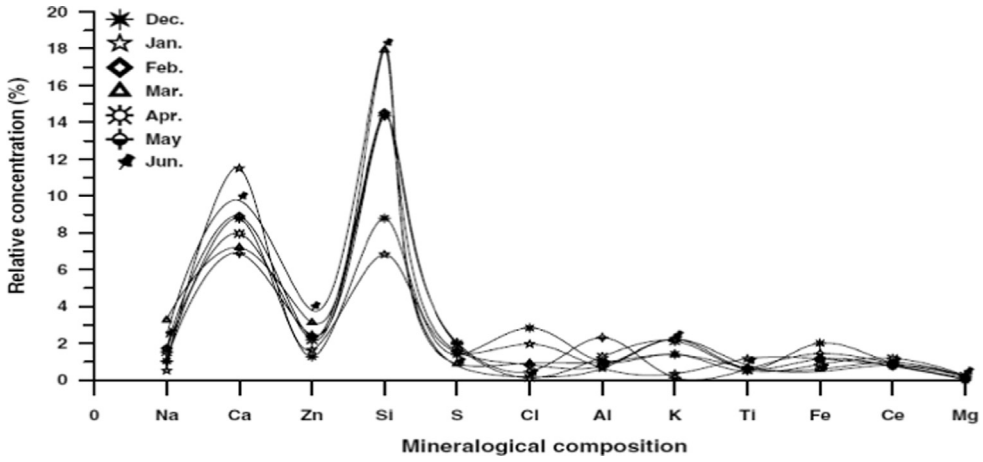


**Fig. 1.** X-ray diffraction analysis of the polluting material [18].