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Dust effect on solar energy systems and mitigation methods

Outline

- Introduction
- Dust properties and factors affecting dust accumulation
- Dust impact on Solar PV systems
- Dust impact on Concentrated solar power technologies
- Mitigation methods
- Conclusions & Recommendations

Introduction

- Actual global energy situation: Increasing electricity demand and environmental concerns
- Generating electricity form the Sun into main forms:

1- Direct (PV)

2- Indirect (CSP)

- UAE energy strategy 2050 (50% of clean energy in the total energy mix)
- Good solar energy exposure: 1900 kWh/m^2<GHI_{annual}<2300 kWh/m^2 and 1600 kWh/m^2<DNI_{annual}<2100 kWh/m^2
- One of the main challenges that deteriorate the performance: **DUST ACCUMULATION**

Dust properties and factors affecting dust accumulation

- Nature of soiling change form location to other in the world
- Dust deposition is influenced with three main factors

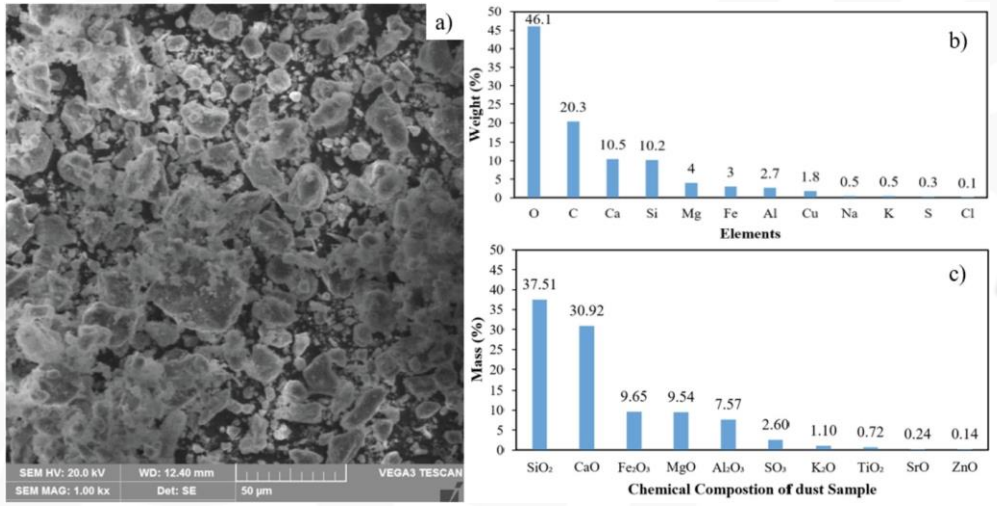
Dust properties
size, composition

Environmental factors
wind, humidity, temperature rainfall

Installation factors
installation site, tilt angle, orientation, height, surface property , texture

Dust properties and factors affecting dust accumulation

- The dust size and composition has an important impact on the shading effect and the performance degradation
- Small size dust tends to block more light with fewer voids
- Dust characterization tests were conducted on a sample at University of Sharjah



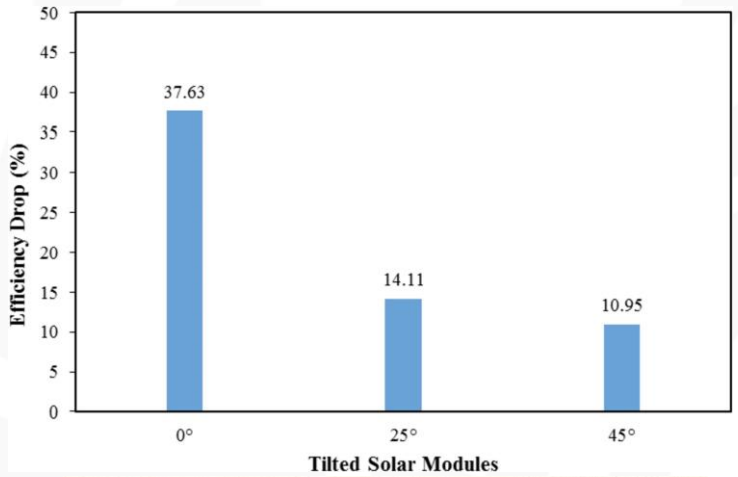
95% of the dust particles are below 25 µm

SiO_2, CaO, and Fe_2O_3 are the dominant minerals

Potential risk of cementation process (sticky and adhesive) under effect of wind and humidity

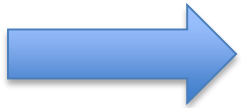
Dust properties and factors affecting dust accumulation

- The tilt angle may change the dust density and the solar energy systems performance in a non-linear way
- The drop of PV efficiency is higher for horizontal surface and decreases when the PV module is tilted due to gravity of dust particles and wind conditions



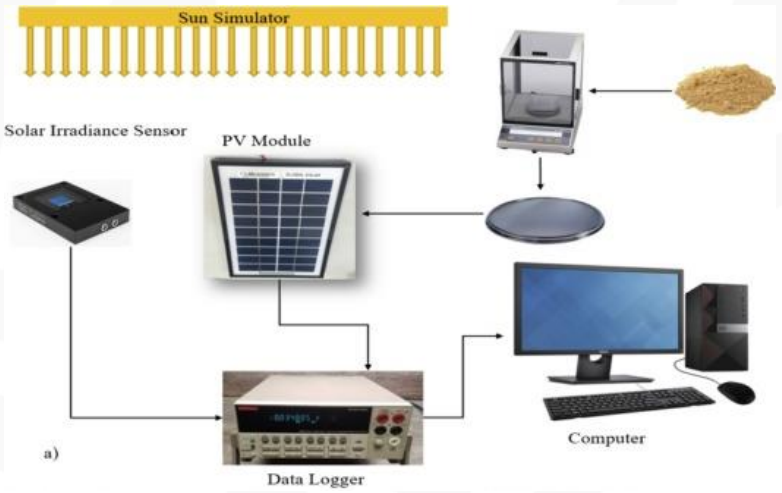
25° could be a **favorable tilt angle** for both purposes: low effect of dust accumulation and optimal tilt angle for incident radiation (Latitude in UAE about 25.4 °N)

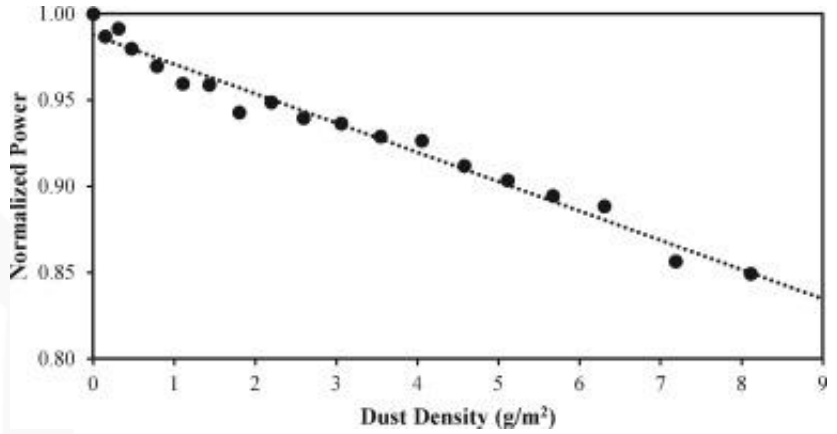
Dust properties and factors affecting dust accumulation

- Wind velocity increases with the altitude  Dust deposition reduces with the height
- Dust settlement densities increase with the decrease of the surface temperature
- Humidity improves the stickiness and adhesion of dust element
- Heavy rain can un-soil the top surface but light rain with less duration may increase the dust deposition
- The front surface property, texture or additional coating can influence the dust accumulation on the solar energy device
- Dust accumulation depends on the exposure time to outdoor conditions: high at initial phases and moderately steady at higher time exposure

Dust impact on Solar PV systems

- Dust accumulation can influence electrical, optical and thermal characteristics of the PV module
- Experiments were conducted under indoor conditions to eliminate the effect of other weather conditions (irradiance, temperature, humidity)

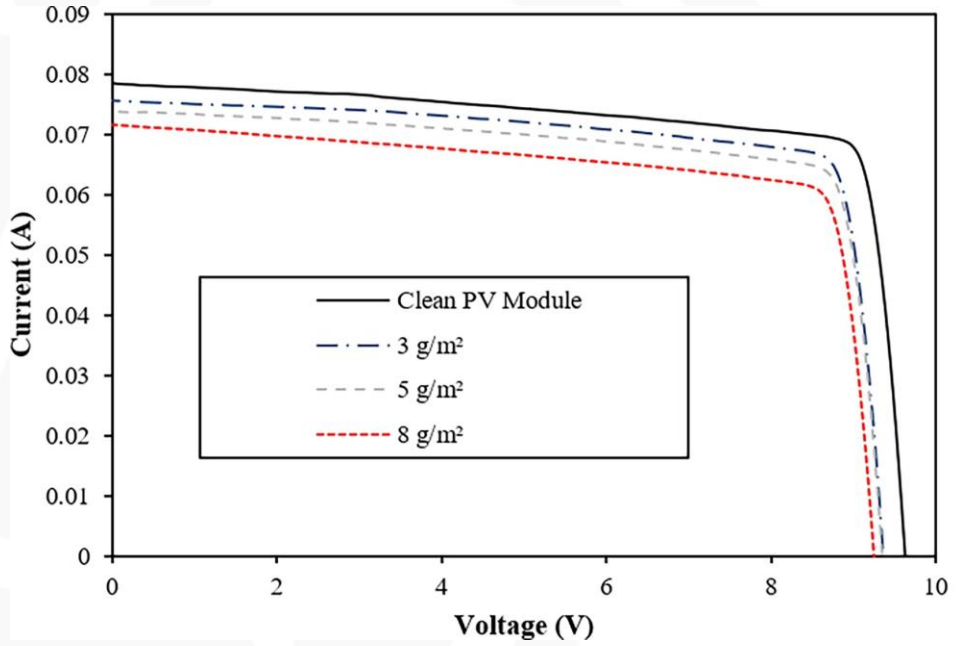


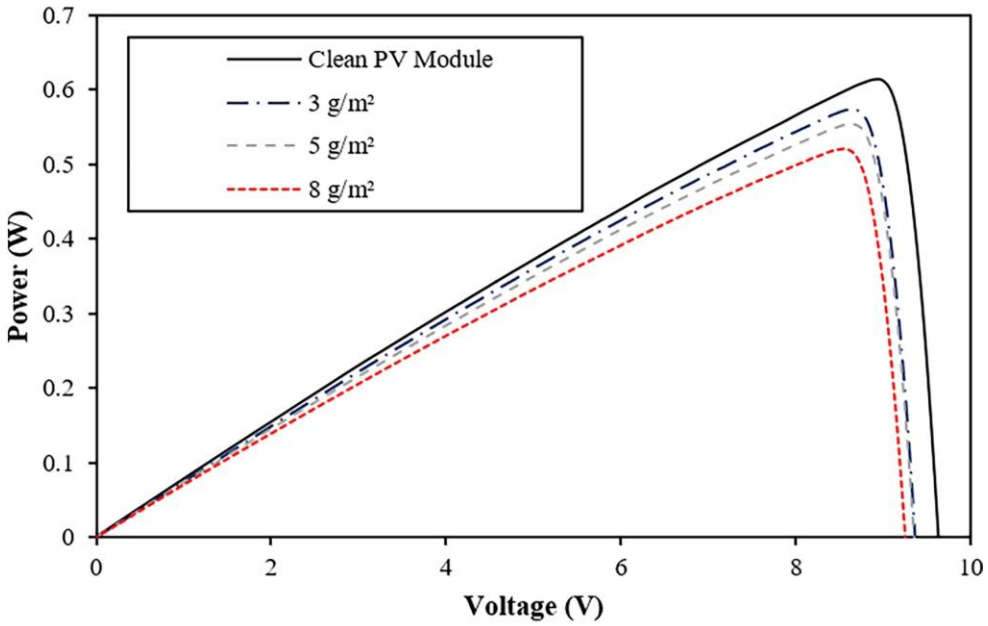


Normalized power drops linearly by 1.7% per g/m^2 of dust density and about 15% of decrease in power

Dust impact on Solar PV systems

- Open circuit voltage dropped by 4.25% while the short circuit current dropped by 8.78% when increasing the dust density from 0 to 8 g/m^2

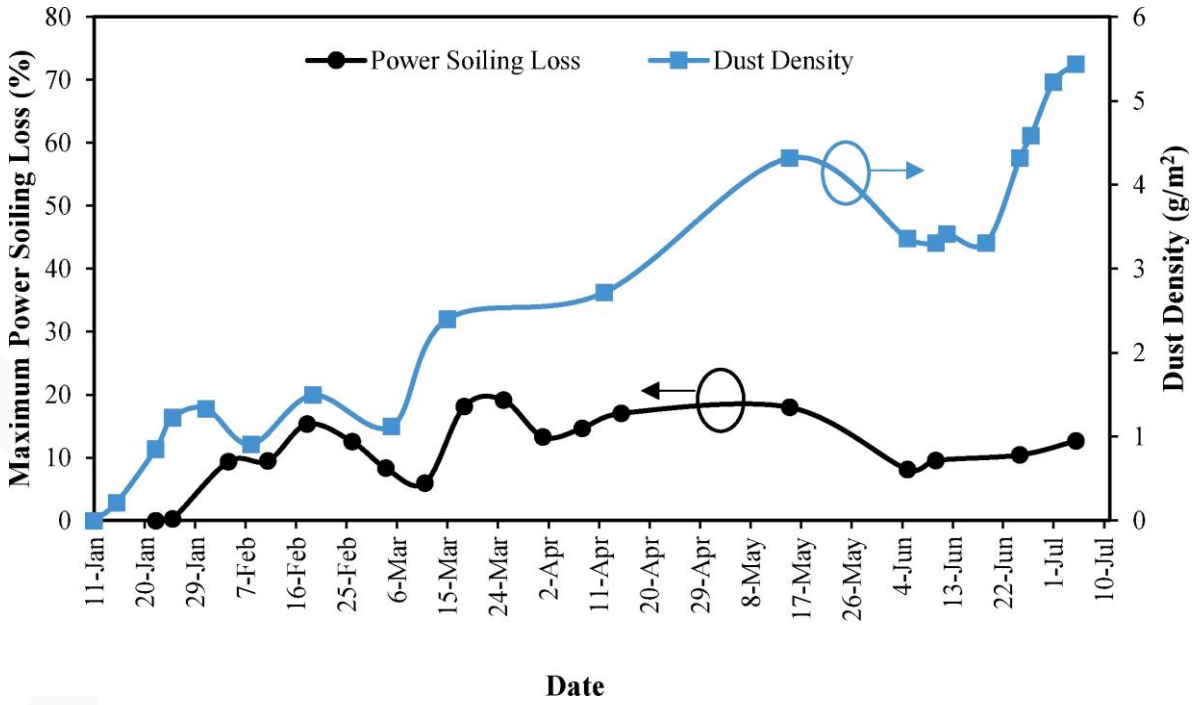




Dust impact on Solar PV systems

- Outdoor experiments were conducted over more than 5 months to investigate the dust effect under UAE conditions

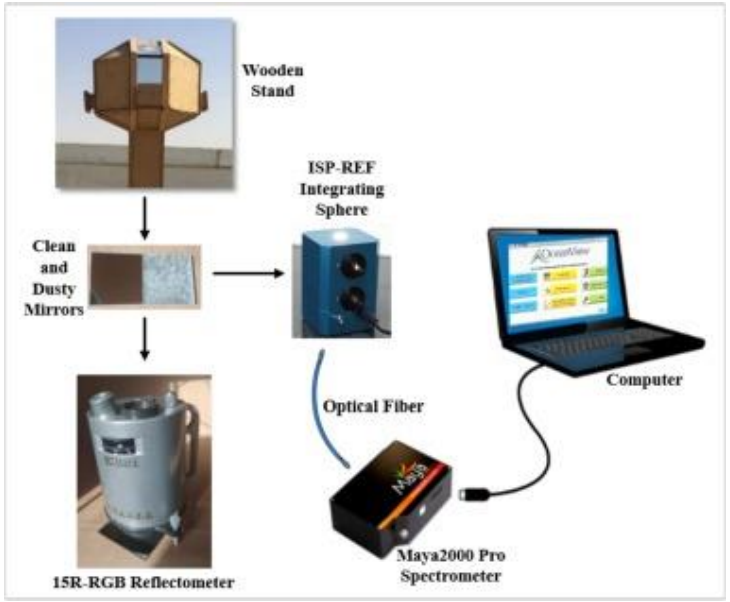
  - Soiling loss of PV power increased from 0.29% to 12.7% while the dust density increased from 0 g/m2 to 5.44 g/m2
  - Power soiling is not constant and is strongly dependent on the local weather conditions
  - Both power soiling and dust density decreased in the period of rainfall, which participates in cleaning the panel naturally, and increased during sand storms weather events



Dust impact on Concentrated solar power technologies

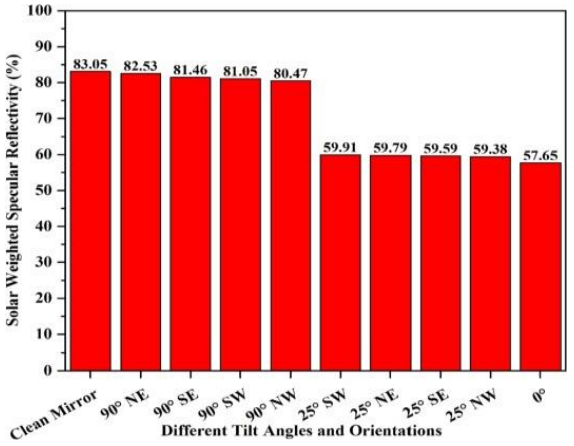
- Concentrated solar power technologies (parabolic trough, solar tower, Fresnel collector, parabolic dish) use reflective surfaces to concenter the solar rays
- Any small loss in reflectivity could lead to major deterioration of the system performance

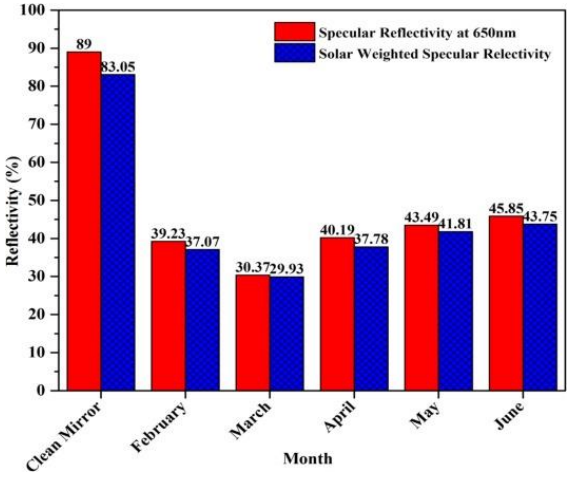
  - Various experiments were conducted to understand the soiling effect on silvered-glass mirrors
  - A wooden stand was designed with three different inclination angles and orientations
  - Specular reflectivity is the main parameter to evaluate and assess solar reflectance properties of CSP mirrors



Dust impact on Concentrated solar power technologies

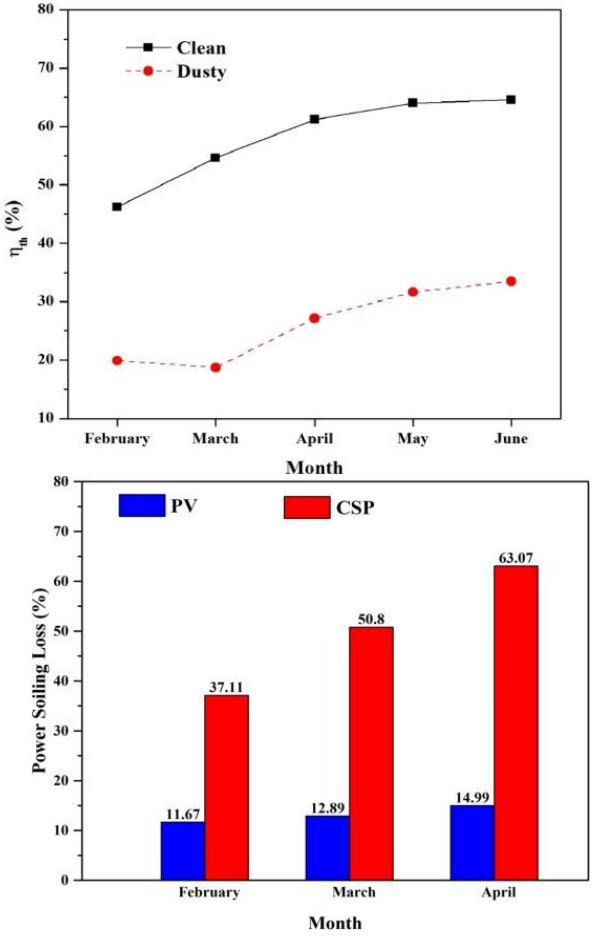
- The solar weighted specular reflectance increased as the inclination angle increased due to the gravity, which helps the dust particles to fall down.
- The monthly dust accumulation was investigated for five consecutive months by placing the CSP mirrors tilted 25° south
- The relative reflectivity drop was varying from 47% to 64% depending on the accumulated dust and the influence of weather conditions
- The lowest reflectivity (around 30%) was recorded in month of March (high relative humidity at this month)





Dust impact on Concentrated solar power technologies

- To understand the impact of dust on the CSP performance, simulations were performed on LS2 PTC using the experimental data of specular reflectivity.
- Dust accumulation has a major contribution in the deterioration of the PTC performance with a drop in thermal efficiency varying from 26.4% (in February) and 36% (in March).
- Power soiling loss for CSP is 3–5 times worse than PV → higher reflection losses and the interaction of the dust particles with the solar rays in its double trajectory through the glass mirror.



Related publications

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Impact of dust on the performance of solar photovoltaic (PV) systems under United Arab Emirates weather conditions

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ABSTRACT

The performance of PV systems is generally affected by the real weather conditions. In the desert climate, dust accumulation is one of the main concerns that may cause a significant deterioration of PV efficiency. In the present work, experimental investigations were carried out to understand the dust characteristics and its effect on the electrical performance of PV modules under Sharjah, UAE weather conditions. The morphology of the dust sample indicates that dust particles have different shapes and small sizes (1.61 −38.40 μm). The results of the indoor experiments reveal a linear relationship between the dust density and the normalized PV power with a drop of 1.7% per g/m^2. Dust accumulation is a function of the tilt angle and it increases by 37.63%, 14.11% and 10.95% with respect to the clean module for the 0°, 25° and 45° tilted modules, respectively. Outdoor experiments showed that the soiling loss increased by 12.7% while the dust density increased by 5.44 g/m^2 for a period over 5 months. By comparing the results of indoor and outdoor experiments, it was concluded that the linear relationship is reliable and can be used to predict the soiling loss of PV systems in UAE and similar weathers conditions.

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Numerical and experimental investigations of dust effect on CSP performance under United Arab Emirates weather conditions

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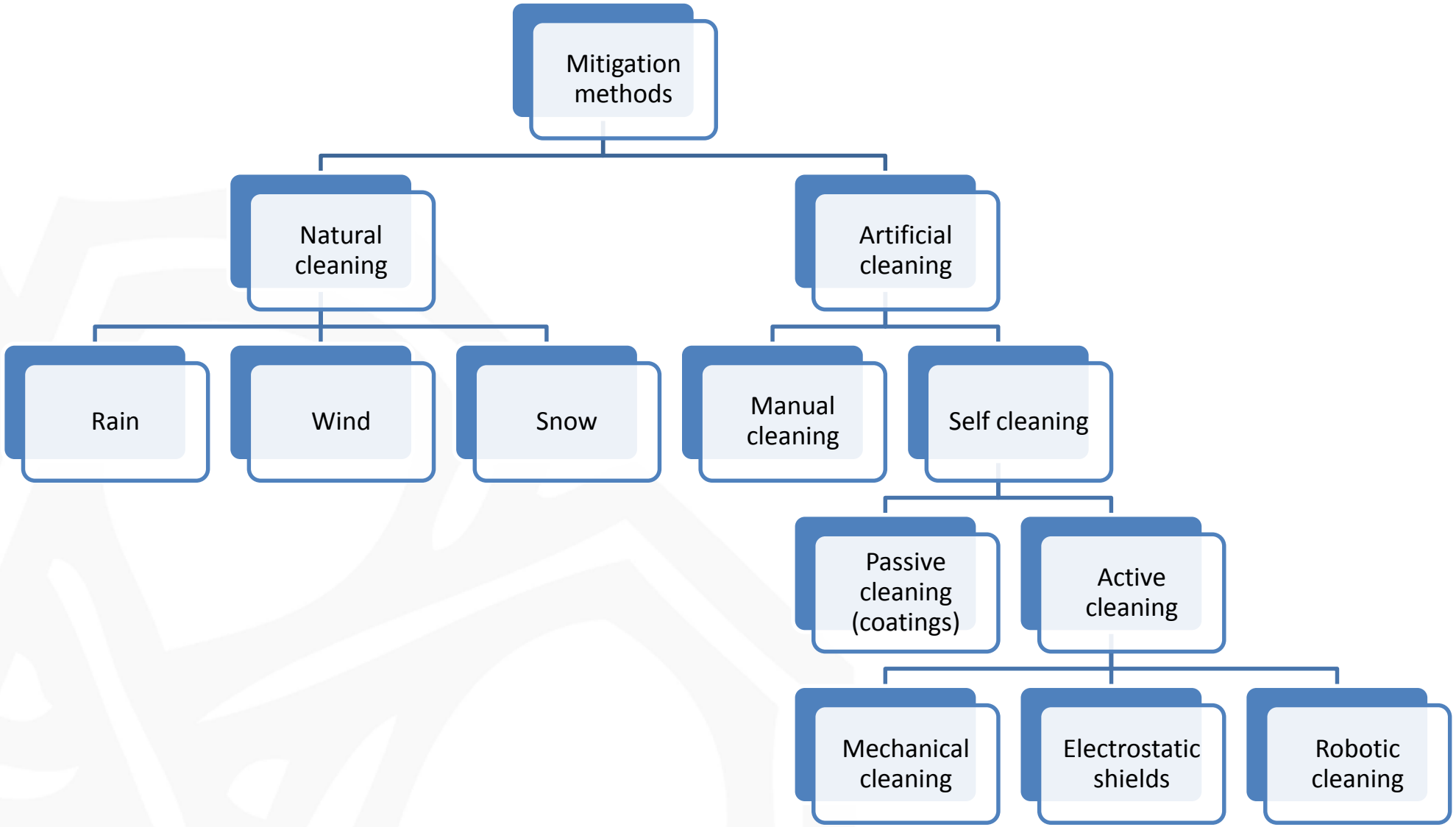
ABSTRACT

Dust is one of the main challenges in implementing concentrating solar power (CSP) systems in arid and semi-arid zones. The characterization of dust particles and the measure of the soiling loss effects under real operating conditions can be useful to select the appropriate cleaning methods and frequency. In this study, experimental and numerical investigations were carried out to study the characteristics of dust particles and their effects on the CSP performance under UAE weather conditions. The results showed that the soiling rate is correlated to the wind speed and direction. The monthly soiling effect was evaluated for 5 months of exposure with the highest decrease recorded in March. The results of cumulative dust experiment showed a drop in specular reflectivity by about 63% after 3 months of exposure. Based on the experimental data, the power soiling loss and thermal performance were determined for a parabolic trough solar collector. The predicted results were in consistence with the dust accumulation leading to a 36% decrease in thermal efficiency. In addition, the power soiling loss was compared with that of PV technology, and it was found that soiling effect is more pronounced in CSP systems by 3 −5 times drop in performance.


Mitigation methods
Natural cleaning
Artificial cleaning
Rain
Wind
Snow
Manual cleaning
Self cleaning
Passive cleaning (coatings)
Active cleaning
Mechanical cleaning
Electrostatic shields
Robotic cleaning

Conclusions & Recommendations

- Dust accumulation depends on dust characteristics and properties, location and environment parameters.
- Dust accumulation not only influences the performance of solar energy systems but also reduce the lifetime of these devices.
- There is no fixed cleaning method but it depends on the site and weather conditions.
- Periodic cleaning is recommended for moderate dust accumulation.
- Optimize water usage during cleaning and adopt water recycling.
- Preventive approaches are recommended such as passive methods (coatings) or active (EDS). The economic feasibility and lifetime of such solutions need to be further investigated.

Thank you