Performance Analysis of Solar Powered Disinfection System for Prevention of COVID Infections

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Abstract - A desperate desire to prevent the COVID virus has emerged since its outbreak which has consumed several lives in the past one year. Active researches have led to vaccine development which is still in early stages. The present system is an amalgamation of tunnel disinfectant spray system and solar setup which utilises the solar energy to power a pump which pushes the required amount of chemical mixture into the nozzles of the spray system. Data was gathered for a mall in UP related to occupancy levels before and after lockdown. A 53 % and 38 % spike in energy and disinfectant mixture to pump was evaluated on weekends. A 75 % reduction in operating cost was registered for solar based system in comparison to non-solar setup. Optimum conditions by considering efficiency and cost effectiveness evaluated are 10 numbers of nozzles, nozzle angle 58 degrees and spray pressure 220 bar.

Keywords: Spray disinfection tunnel, solar energy, Covid -19, solar PV cells, mist system

I. INTRODUCTION

The present world has run into deep trouble since the emergence of a deadly virus known as corona virus (Covid-19). Earlier viruses like swine flu and MERS were also considered dangerous in several countries [1,2]. So far, these viruses consumed several lives in a span of a few months but also has resulted into loss of property, money, time, jobs etc, thereby by severely disabling people from their normal lives and cope with harsh living conditions [3,4]. Recent studies have also predicted the deadly virus to be airborne which could make the virus spread at a tremendous rate among groups or large gathering among people [5-7]. Active researches are being carried all over the world to find a suitable cure or vaccine or medicine that could prohibit its spread among community [8,9]. So far testing is being carried out in worlds top research institutions and is the top priority among people [10]. But to the worlds avail no positive results have been obtained since the outbreak of the corona virus [11]. The vaccine developed Sputnik V has shown certain side effects in 14 % of participants, thereby making people susceptible of it [12,13].

In anticipation of a viable vaccine, people have taken an initiative of self-care but regularly washing their hands, clothes, wearing masks and face shields. Keeping pocket sanitizers for regular hand wash has become a common practice all over the world. People are living in homes and isolating them from the world to prevent catching the virus. Active steps by the government all over the world are being taken like complete or partial lockdown and sanitizing the public areas [14,15]. But the recent economy disasters have enabled the world to live with this virus rather than avoiding it [16,17]. This probably is the right option, since people all over the world are losing their jobs, particularly the daily wages worker who may die out of hunger rather than the corona virus if lockdown continues [18,19].

Various sanitizing machines are being installed in public places or places having huge gathering [20-23]. One of them is the disinfection tunnel spray system which can sanitize any incoming person in these gathering with sanitizing/person ratio being comparatively higher than other technologies [24-26].The mist disinfection tunnel system primarily sprays a correct required amount of chemicals in the tunnel in order to kill any bacterial or virus being attached on to the clothes of the incoming person [27]. In recent months many public places such as airports, factories, railway station, hotels, banks, supermarkets, college campus, malls, marriage halls and religious gatherings are employing this device to disinfectant incoming people [28]. A specific pupil entering the tunnel needs approximately less than twelve seconds to render him completely infection free [29-31]. The individual walking inside the tunnel consumes approximately 0.64 litre of chemical mixture in the form of external spray mist. Chemical such as hypochlorite was used in varying amounts between 0.02 per cent to 0.05 per cent weight concentrations [32].

This model is based principally on the analysis of the experimentation results using the available data from occupancy, solar radiations based on location and experimental setup. The research analysis was performed for a mall located in New Delhi known as Living style mall, Jasola is selected for experimental analysis. The setup was installed at the entry of the mall in order to understand various parameters such as number of people entering the mall, pump power requirements, water usage, time of the day, amount of chemicals needed, variation of water-chemicals requirements for various days, optimum

 DOI : 10.35291/2454-9150.2021.0012

hydraulic and room conditions and comparison between a solar and non-solar setup.

II. EXPERIMENTAL METHODOLOGY

2.1 Concept and advantages of disinfection tunnel misting system

The solar setup was integrated with various devices (HVAC, Refrigeration, distillation, power plant, and solar pump) with successful results in previous researches [32]. The disinfection misting system particularly involves water and chemicals mixed in suitable combination forced through the pump in to tubes attached at various point in the tunnel were nozzles are attached at appropriate points facing the incoming person. This high-pressure nozzle emits disinfectants in the form of micro fine mist particles which remove any bacteria adherent to the body of the person. Tubes are mostly made up of stainless steel or brass. The water droplets after the action of eliminating the virus is instantly flash evaporated in to the environment. The tunnel system detects any incoming person from a distance of 10-30 cm thereby getting ready for its operation. The ideal detection method the tunnel employs is by infrared radiations which pre-warn the system of any activity inside the chamber. The infrared radiation measures the temperature of the incoming person with a collection accuracy of ± 0.5.

The present technology uses a combination of solar powered pump and misting system which uniformly distributes chemical spray on the clothes of the incoming person. Earlier solar based pumping resulted with good results in earlier researches [33, 34]. These systems are quite efficient in operation with lower overall cost. The presence of solar equipment in the setup also recovers the cost of the equipment in due course of time as this equipment would have worked on normal electricity could have consumed substantial amount of electricity, thereby having a huge amount to pay at the end of the month. The solar equipment is completely self-dependable equipment using solar energy to produce the required action of misting chemical mixture. The chemical disinfectant mixture is assumed to be so fine that there is absolutely no chance of wetting the system. Its effect can be compared to that of a particular person standing under the fog. The person becomes free from bacteria and viruses but does not degrade the cloth material and wet it. The incoming person needs to stand at a specific position pre indicated by a yellow colour square drawn at the ground. This yellow safe square is a pre indicator to the incoming person as a reference standing position. The square is placed in the middle where all nozzles are directed towards. In order to safe guard the eyes of the person useable goggles are given to the person who can be discarded off later in the bin. The goggles are reused after sanitising them at regular basis. The person is supposed to stand approximately 20 cm away from the nozzle to avoid wetting himself. Water chemical mixture is free from harmful toxic chemicals that may affect skin. The complete setup is quite compatible with the solar integrated system as the system applies a ratio of 1:3 for chemical and water combination as spray disinfectant to completely sanitize them from viruses and bacteria. Also a strain filter is attached to the water system before entering the pump to draw out any incoming impurity which may eventually clog the nozzle.

Appearance of a typical Disinfection misting system during the study is shown in Figure 1.

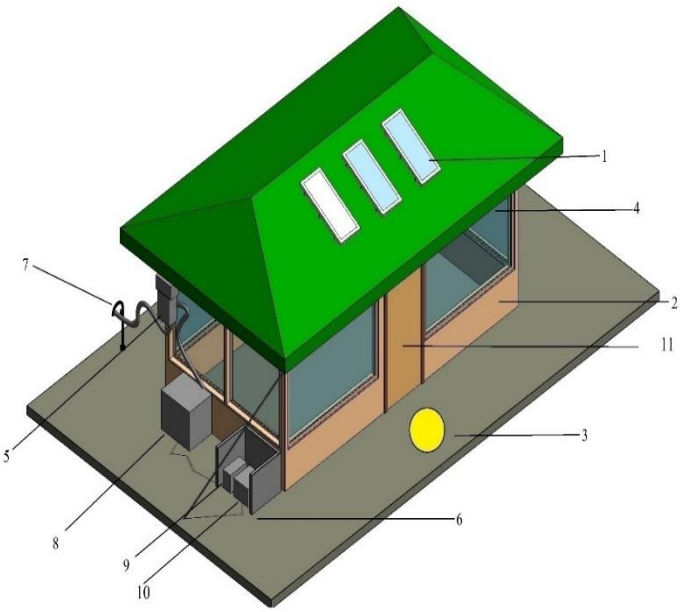

Figure 1: Typical Disinfection Misting System

The present situation in New Delhi based on number of corona virus cases are specified below in the Table 1.

Table 1 Summary of Test Results (National Health Mission 11-01-2021)

Parameters	Number Reported
Samples tested	631000
Death	10,691
Positive %	15.22%
Tests per million people	308,792

2.3Uncertainty study of the experimental measurements

In order to evaluate the various errors in the model a testing system was applied which accurately estimated the errors associated with the study and thereby is formulated below in Table 2.

Table 2 The measurement accuracies and experimental uncertainties associated with sensors and parameters

Sensors and Parameters	Accuracies and Uncertainties measurement
T-type thermocouples	±0.4 C
Flow meter	±4 ml
Pressure transducer	±0.8 mbar
Voltage measurement	±0.06 V
Current measurement	±0.15 A
Silicon Irradiance Sensor (SiS sensor)	±5 W/m^2 ± 3.5% of measurement value
Power Temp Coefficient	-0.29%/C

 DOI : 10.35291/2454-9150.2021.0012

The total percentage of uncertainty is determined in this experiment by applying the Holmanns equation [35] provided below:

The total percentage uncertainty = square root of [(uncertainty in T-type thermocouples)^2 + (uncertainty in Flow meter)^2 + (uncertainty in Pressure transducer)^2 + (uncertainty in Voltage measurement)^2 + (uncertainty in Current measurement)^2 + (uncertainty in SiS sensor)^2 + (uncertainty in Power Temp Coefficient)^2]

The total percentage uncertainty = Square root of [$(0.4)^2$ + $(0.005)^2$ + $(0.8)^2$ + $(0.06)^2$ + $(0.15)^2$ + $(4)^2$ + $(0.29)^2$]

The total percentage uncertainty = ± 4.29 %

Hence the total uncertainty associated with the system comes close to 4.29 % which for the analysis of a solar setup is suitable, satisfactory.

2.4 Study location analysis

A general estimation and prediction were assumed before the lockdown on previous data so as to interpret the number of people entering the mall. The graph below shows the variation in occupancy before and after the lockdown for the specified mall.

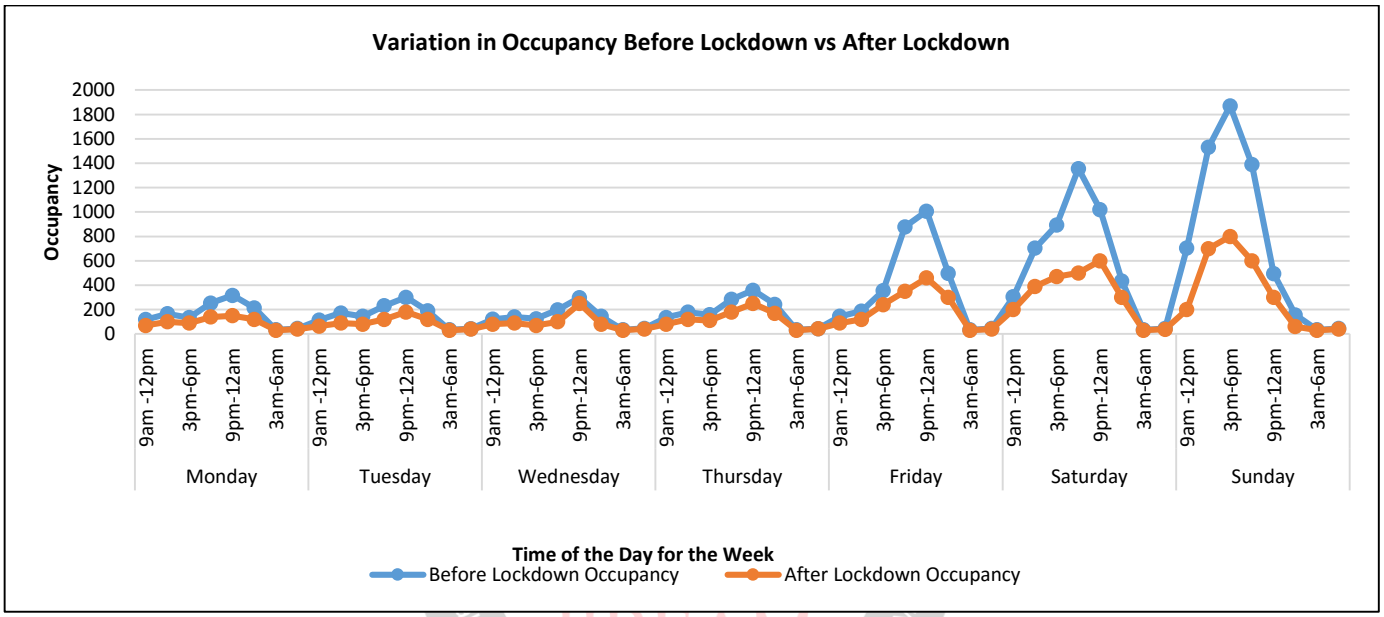

Figure 2 Variation in occupancy before and after the lockdown for the mall

The average prediction after mall opening can be seen in the data as soon as the mall opened and restriction eased the general idea that people will avoid coming to the mall which was quite true till one month after which people started coming in large numbers. Hence to some extent this device will enable a Covid-19 free environment enabling people sanitised and easily come to the mall based on their requirements.

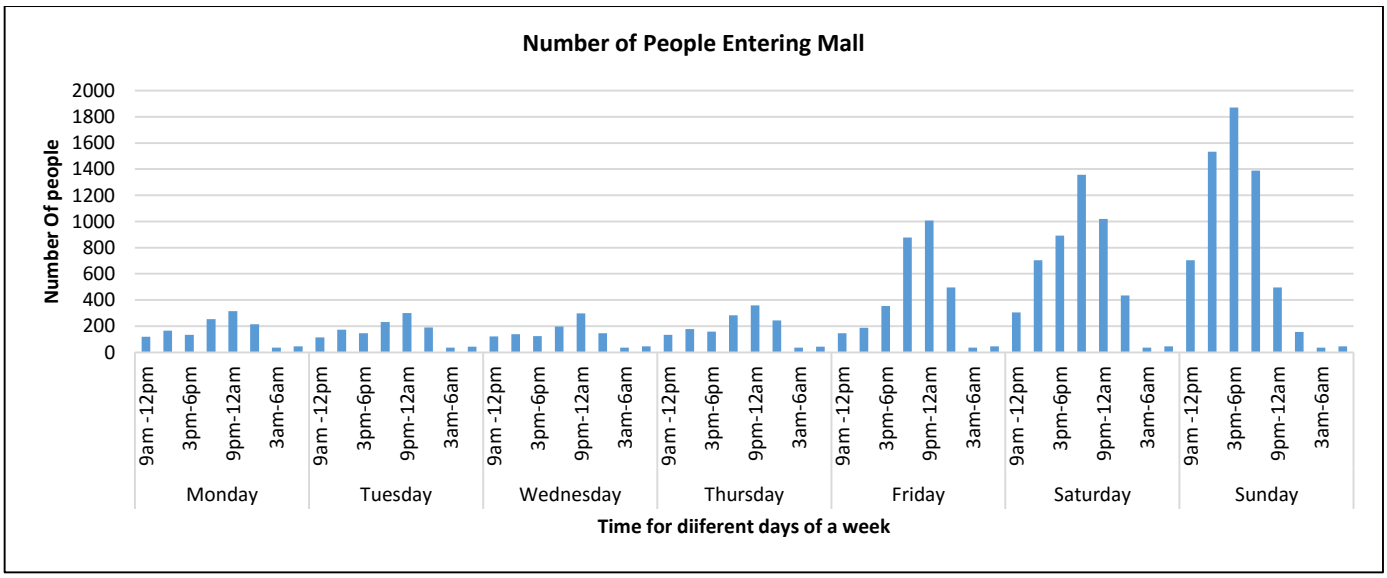

Figure 3 Number of people entering the mall for the entire week

 DOI : 10.35291/2454-9150.2021.0012

Another graph explaining the trend followed by the incoming people in the mall throughout the week is studied, in order to pre order the requirement for preparing chemical mixture disinfectant. The maximum number of people is seen to be entering in the mall on Friday and Saturday which is a weekend and families prefer coming on Sundays. Hence the graph shows the peak on Sunday afternoon followed by Saturday afternoon and evenings. Apart from these days the other days are more or less similar in terms of incoming people as these people go to the office and only prefer weekends to shop and eat. In terms on number of people entering the mall on non-weekend days, the highest spike is registered between 6pm -9pm when people are returning back maybe picking groceries and eatery items while going back home.

III. SYSTEM SETUP

The setup primarily comprises of a solar PV cell attached at the top of enclosure denoted by 1. Point 2 denotes the enclosure which is made up of mild steel. The incoming person needs to stand on the elliptical yellow space point 3 for temperature detection from IR detector attached at the top of the incoming enclosure at point 11. Further point 4 specifies one sprinkler attached at a certain height where all other sprinklers are attached in series at same height. Point 5 denotes all the box containing electrical connection like transformer and relay. Point 6 is the charge regulator connected between inverter and battery system. Point 7 shows the pipe diverted to the tank to extract disinfectant mixture. Point 8 shows the water mist pump which in turn is connected to point 9 and point 10 which are the battery and inverter system of the solar setup.

3.1 Hydraulic setup

The primary area of concern was the hydraulic components which comprised of equipment's applied to issue water through the nozzles. It consisted of a water misting pump, cartridge filter, piping system, ring connector and nozzles. The pump attached is basically of 1 kW power of high pressure programmable infra-red sensor mist type, working between pressure of 140-200 bar. The pump is place above the spray room setup besides the solar setup. The specifications of the pump are AC 165-220 V, 50 Hz, and single phase. The water drawn in by the pump from the storage tank requires a cartridge filter in order to remove any impurity or sediment present in the water, which may eventually clog the nozzles. Further the piping required to connect the outlet of the pump to the misting room inlet is made up of an all-weather resistant nylon hose pipe, especially designed to withstand the misting pressure. The required length of nylon pipe is roughly 4 m with outer diameter of is 1/5th of an inch or 50.8 mm.

Figure 4: Equipment's for spray mist system

3.2 Tunnel enclosure description

The main frame was made up of Mild steel material with 6 mm poly carbonate covering the tunnel. The room dimensioning are 30 x 30 x 3 having a per meter weight of 2 kg in Figure 1.

 DOI : 10.35291/2454-9150.2021.0012

Table 3: The main components specification and characteristics of the solar disinfection spray system

S. No	Element	Technical specification	Number of elements	Price (Rs)
1	Solar cell	Loom Solar 180 Watt V Mono Crystalline Panel	2	18000
2	Inverter	Luminous 30 A, output 220 VAC, 1800 W	1	28000
3	Solar battery	Luminous LPTT12150H 150Ah Solar Tall Tubular Battery	1	13000
4	Charge regulator	Techtest 10 Amp Solar Charger Controller Panel Battery Intelligent Regulator with USB Port LCD Display 24/12	1	4000
5	Solar cell fasteners	UV protected multi-contact solar cables and connectors (5 m), power cable (8 m)	1	15000
6	Pressure water pump		1	40000
7	Miscellaneous	Room enclosure, hexagonal nozzle series: 0.2 mm, number of nozzles: 8 units, clamps, pressure switch, pump regulator, terminating line, highpressure copper pipe, clips, quick fittings, purge valve, T-connection, L-connection, pipe holder, filter, pressure gauge.	-	5000
	Total price			1,23,000

IV. RESULT AND DISCUSSION

In this paper, a novel combined solar-based disinfection tunnel system for a mall is designed, developed, and analysed. A performance based parametric analysis is initiated by varying aspects of operational parameters. Complete analysis of the research is exclusively explained in upcoming sections herein.

4.1 Pump power requirements on daily basis

The pump power requirements for various days of a particular week were evaluated in Watts as depicted in the given figure. The general trend followed by occupancy is displayed as a rise was registered during afternoon and evening since people leaving the office visited the mall for various reasons. Further a spike in occupancy level was seen for the time frame 3pm-6pm thereby requiring higher energy to pump the disinfectant mixture. Hence during the above time interval surplus amount of disinfectant mixture should be ready for the incoming people to be sanitized. Highest number of people came in on weekends (especially Sunday), hence additional power maybe required by the pump to operate in such circumstances.

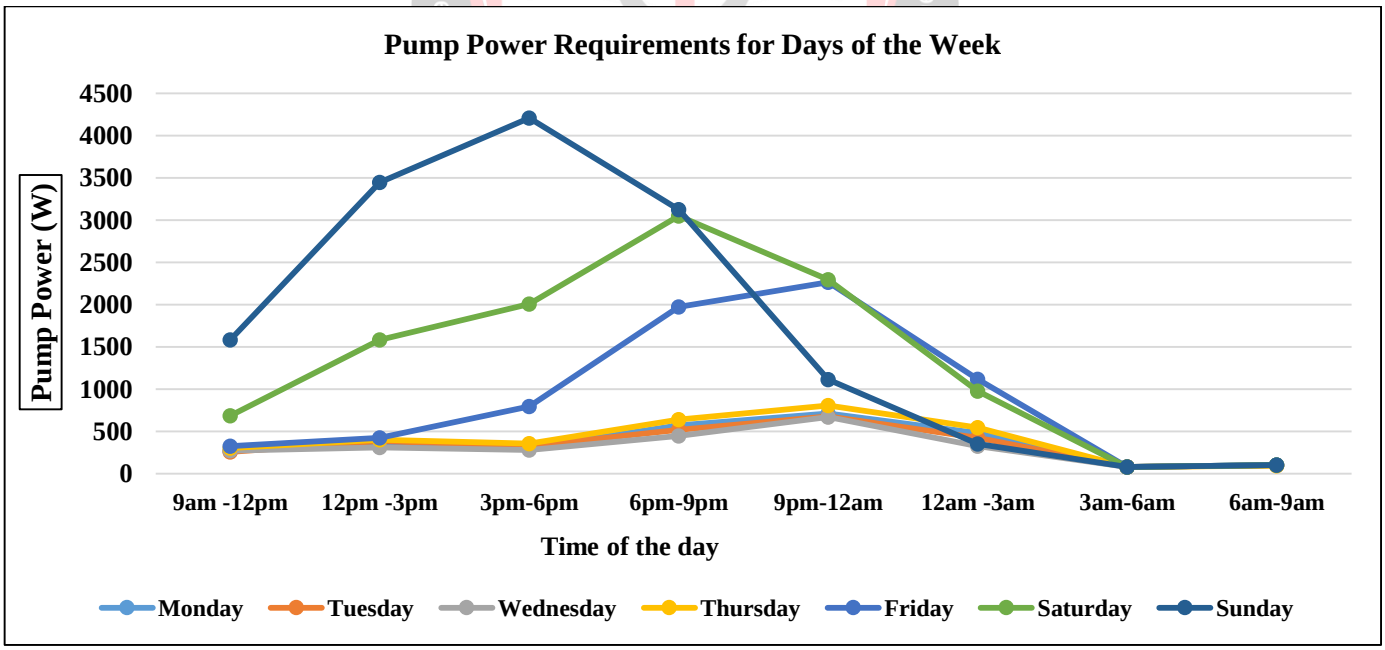

Figure 5 Variation in pump power for different days of the week

4.2 Disinfectant requirements for different days of the week

The current situation after lockdown has displayed a sense of unpredictability in the minds of the population. Thereby the mall owners should pre-order the disinfectant mixture sprayed on the people for smooth functioning of without stopping entry into the mall. Highest occupancy was recorded during afternoon and evening, thereby requiring higher quantity of disinfectant mixture to be pumped. Biggest spike in disinfection requirement was seen for the time frame 6pm-9pm.

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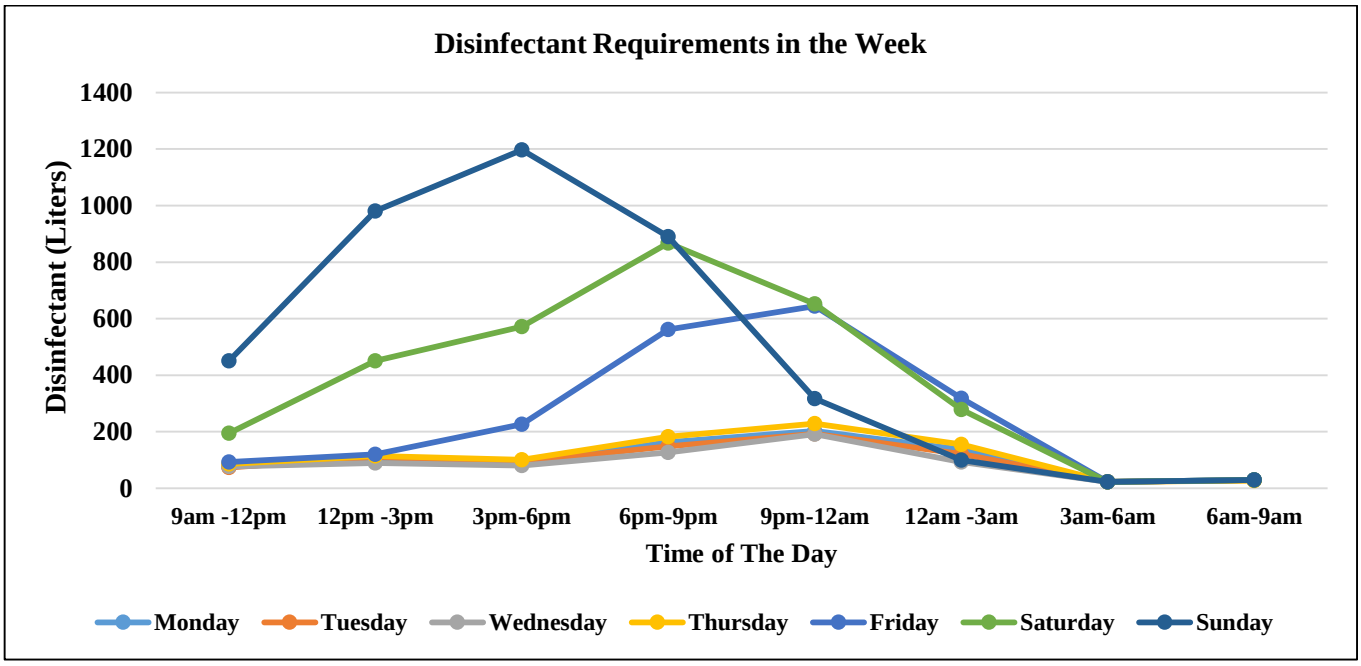

Figure 6 Variation in disinfectant requirements for different days of the week

4.3 Operating cost comparison between solar and non-solar setup

In order to provide a comparative cost-based analysis between solar and non-solar setup, the following graph is presented in Figure. The reading obtained is based on pump requirements in watts and average electricity tariff in India. Generally, most states adopt an Rs 7 per unit electricity cost. The factor of autonomy was also considered while measuring the total pump requirements for the solar setup.

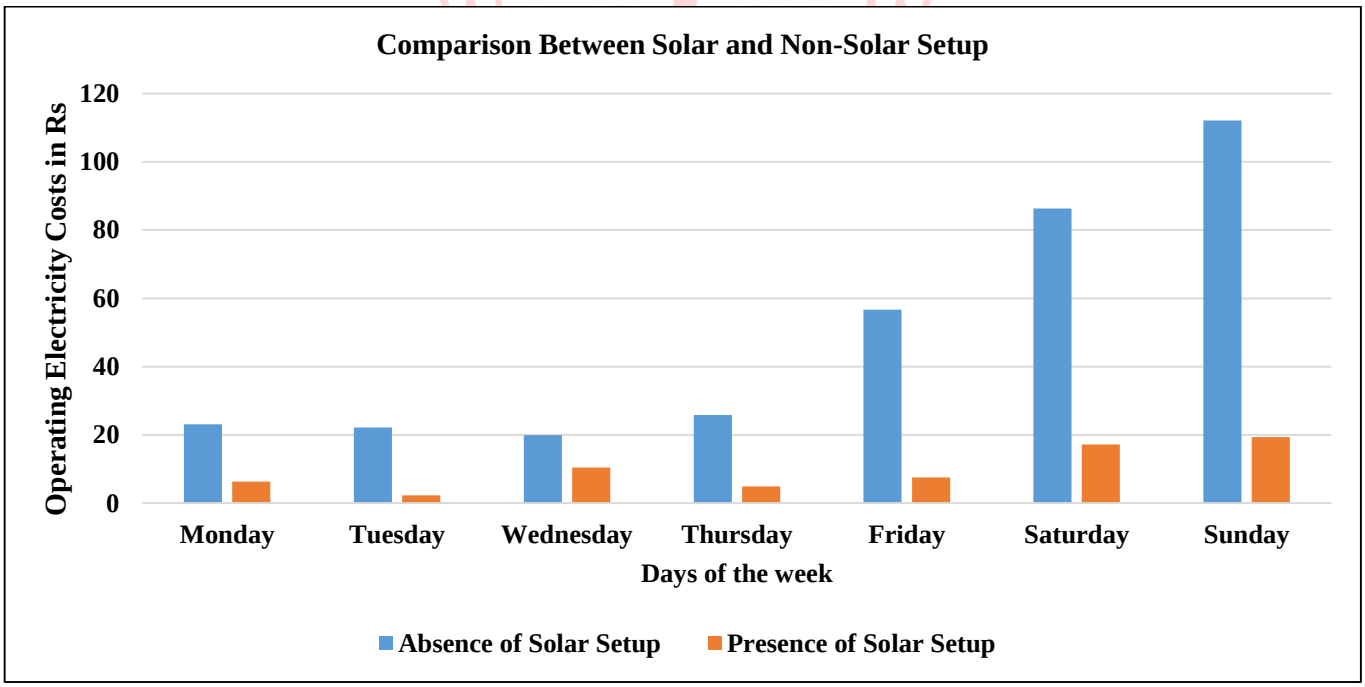

Figure 7 Operating costs comparison for a solar and non- solar setup

4.5 Impact of panel efficiency and solar irradiance on PV output

The current Figure explains the trend followed between the irradiance and panel efficiency for PV power output. The readings were obtained by varying the solar irradiance between 300 W/m^2 to1200 W/m^2. Three different panels with different efficiencies (14%, 16%, and 18%) were selected to further choose the best possible panel with lowest cost and maximum efficiency. A linear rise in overall power generation has been observed by increasing panel efficiency and solar irradiation. The primary reason of choosing efficiencies between 14- 18 % is the limitation associated with PV cells where maximum efficiency achieved so far is close to 19 % only. The above result clearly enumerates that high solar radiance furnishes higher PV output, stipulating that any geographic location

 DOI : 10.35291/2454-9150.2021.0012

having favourable solar irradiance levels will perform better.

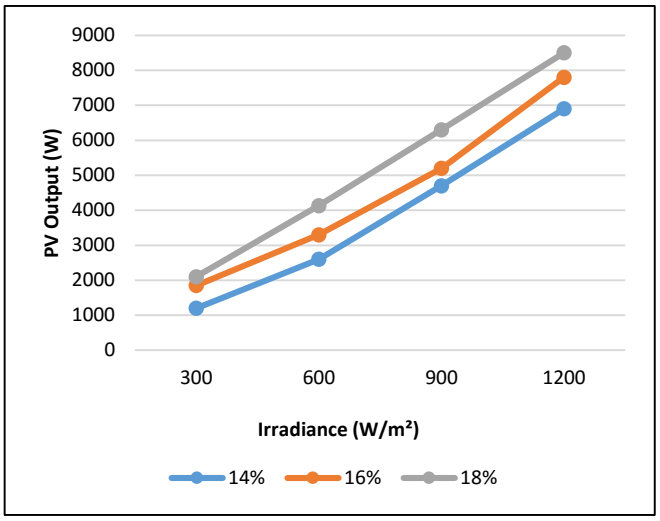

Figure 9 Impact of panel efficiency and solar irradiance on PV power production

V. CONCLUSION

The current study incorporates a combined system which comprises of a solar based disinfection tunnel mist system. The system was developed and analysed by varying several performance-based parameters of the system. In order to facilitate the required energy for the pump, a solar setup is attached which not only provides a clean source of energy but also furnishes substantially lower operating costs in comparison to electricity-based pumps.

The major findings of the current research are explained in points as provided below:

- After the lockdown due to Covid -19, the overall reduction in occupancy level for the mall was close 23.1 % for most days. Further, maximum intake of the mall was seen on weekends where families came in large numbers.
- Further a spike in occupancy level was seen for weekends, thereby requiring 47 % and 35 % surplus energy for Sunday and Saturday in comparison to other days for pumping and spraying the disinfectant mixture. Further for all days, major intake for mall is around 3pmto 6 pm.
- Highest requirement for disinfection mixture was registered during Sunday and Saturday close to 55 % and 43 % respectively. Further during afternoon and evening the total requirement increased for all days of the week.
- Comparatively, lower operating costs was achieved for solar setup of the order 70 % since maximum electricity was procured during pumping action. Zenith operating cost was found on weekends when the occupancy levels were high.
- A linear rise in overall power generation has been observed by increasing panel efficiency and solar irradiation with maximum efficiency achieved in 18 % based panels.
- The total uncertainty associated with the system comes close to 5.34 % which for the analysis of a solar setup is suitable and satisfactory.

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 DOI : 10.35291/2454-9150.2021.0012