

# Comparative Study of Climate Effects on Chimney Operated Solar Power Plant

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**ABSTRACT:** Solar chimney technology deals with generation of electricity using simple parts like chimney, collector and generator. Metrological parameters plays very important role in the efficiency of solar chimney. This paper studies isolation ,wind speed, clear days, relative humidity ,normal radiations as some of the parameters which influence on efficiency of solar chimney. The 22years average data is taken from NASA website. Three cities are considered for comparison for these parameters. The results indicates that the parameters like solar isolation and direct normal radiation are higher for Amravati but some parameters like wind speed and humidity has more influence in Pune affirms the possibility of solar thermal power generation in that region also.

**KEYWORDS:** Solar chimney, solar Isolation, chimney, Turbine, Normal Radiations, Generator, wind speed, clear days

## I. INTRODUCTION

The solar chimney is a promising technology for generation of electricity form solar energy. The solar energy is converted into electrical energy by using three basic parts: chimney ,collector and Turbine. The first solar power plant was developed d in Manzanrus Spain in early 1980 and was run for nearly four years. Since the implementation of this prototype number of efforts are made to study the technological viability of solar chimney. Solar chimney contains four form of conversion of energy. Radiated solar energy is converted to thermal energy in the absorbing device the n conversion of thermal energy into kinetic energy inside the collector ,the kinetic energy is converted into mechanical energy by the blade of turbine and finally the generator convert mechanical energy into electrical energy.[1].

The solar chimney power plant uses green house effect, chimney and wind Turbine in a very innovative way .Here Sun produces hot air under large collector. Diffused and direct solar radiations imposed on the glass roof where some of the radiations may be absorbed some may be reflected and some of the radiations may be transmitted. These radiation quantities depends upon type of glass used, the tilting angle provided on the collector and some of the optical characteristics of glass ,thickness of glass, material of glass, type of big round used under the glass. The multiple reflection of radiation from the collector continues which results in bulk amount of absorbance and transmittance by the ground. The natural convection current setup due to temperature difference inside the collector and outside atmosphere which causes the hot air to rise above the ground and flow towards chimney. Because of this Buoyancy force more air is drawn from the perimeter of the collector. These force convection currents heat the collector more rapidly[2].When the air from collector interface flows towards chimney velocity of air remains constant due to increase of collector height. There is a conversion of heat into kinetic energy by chimney. The density difference determines the chimney base and ambient pressure. the above condition depends upon air temperature at the top of chimney and bottom of the collector. The air from the turbine flows across the turbine, the kinetic energy available across the turbine rotate the turbines and turbine rotate the generator to produce the electricity. The pressure difference can be reduce by the friction losses across the chimney ,entrance and exit air loss. Chimney can be made of various shapes as per requirement as convergent or divergent. The collector can be designed as straight glass top or inclined at some angle.

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Turbine can be located horizontally or vertically and as per power requirement the quantity of turbines can be varied. The size of all these three parts can be varied as per the capacity of power to be generated[3].

The schematic arrangement of solar chimney parts is shown in fig.1.

a) Solar air collector:

Solar collector is like a heat exchanger which absorbs solar radiation and converts it into thermal energy. The collector consists of supporting frames, a transparent roof, and ground. The ground as part of the collector acts as a natural storage device. The capacity of this storage device can be increased by providing black ground or pebbles made of black color which can absorb maximum radiation and can improve the efficiency of the turbine. For continuous day and night power generation, a sealed container filled with water can be placed under the collector which can absorb the radiation during the day along with the collector and emit the radiation during the night which can maintain the temperature of the collector as hot and can carry power production during the night also.[4]

b) The chimney:

The chimney is always situated at the center of the collector. It acts as the heat engine of the power plant. The chimney creates a temperature difference between the bottom collector surface and the top portion of the chimney. Suction is created because of this temperature difference and air flows with more velocity from bottom to top. The chimney of the turbine is extremely high and a stable base is needed for the free flow of air from the collector to the turbine. The chimney is made of metal or concrete as per requirement. The height of the chimney is directly related to the efficiency of the solar chimney power plant[5].

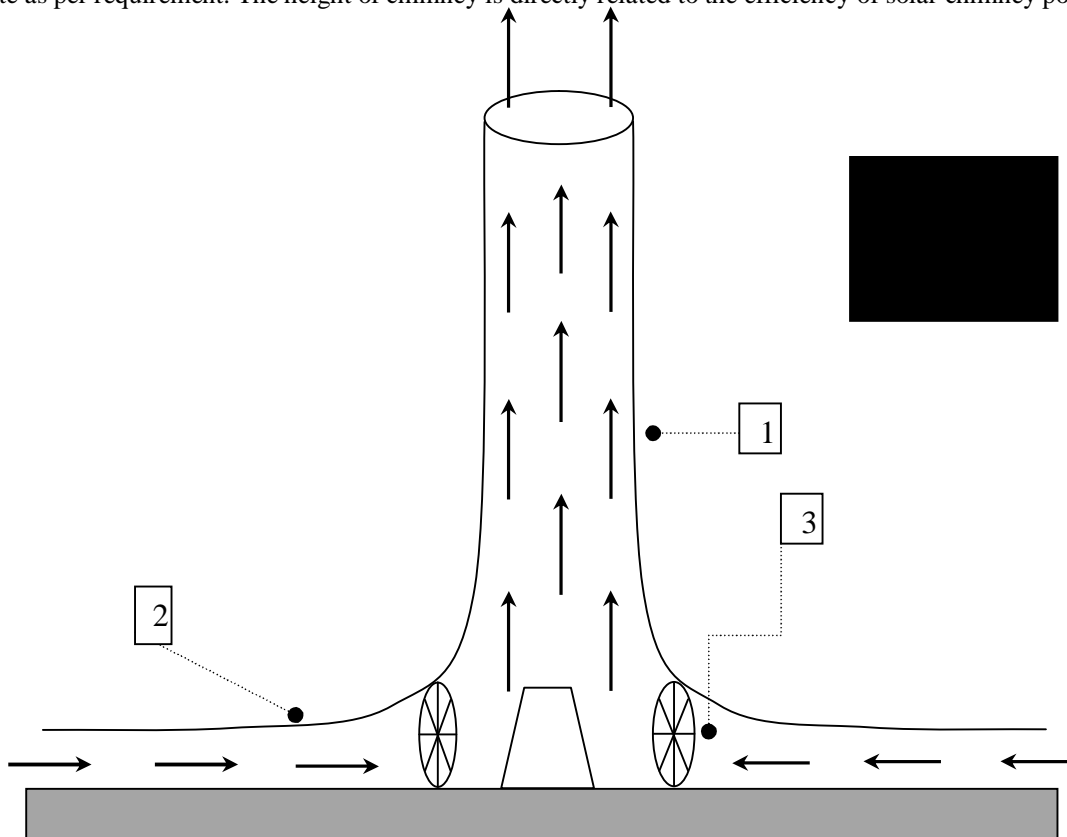


Fig. 1. Main Parts of Solar chimney power plant

c) Turbine:

Turbine is located in the collector and located exactly below the turbine. The main function of the turbine is to extract energy from the hot air and transmit it to the coupled generator. The turbine of this plant is similar to large wind turbines.

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Various types of turbines can be used like the axial type with radial inflow inlet guide vanes which was used in Manzanrus pilot plant. Turbine pressure drop is the important to be considered while selecting the turbines[6].

## II. RELATED WORK

Solar chimney technology is comparatively old technology which was developed in early 1980. The first power plant was set in Manzanrus Spain which run for more than four years and given power output of 50Kw. Many researchers have started their research by keeping this pilot pant as reference. Krist [7] develop four solar chimney models with a output of 10w in USA .A.B.Kasarian et el.[8]investigated the climate effects of the efficiency of solar chimney power plant. He constructed a pilot plant with 10 m collector diameter and 12 m chimney height. He get the temperature difference of 25<sup>0</sup>c between collector exit and ambient air. Miqdam T. Chaichan et el.[9] compared variable Basement kinds of solar chimney prototype in Baghdad. The highest temperature difference reach was 22<sup>0</sup>c and the chimney efficiency was 49 % which was obtained by pebble ground. Amel Dhahri et el.[10] done the detail review of solar chimney power generation technology. He concluded that these system may be of very large size to generate power to a very large extent. Mohammad H. Naraghi et el.[11] done the twenty four hour simulation of solar chimney to conclude that an increase in heat of collector results in a greater air flow rate during evening and early morning hours when the solar irradiance is not so strong. The increase in heat rate varies the air flow rate. A.A. El-Haroun[12] done the performance evaluation of solar chimney power plant in Egypt. He found that the wind speed inside the chimney was 7 times more than the wind speed outside. He also concluded that solar chimney with 500 m height of chimney, 50 m chimney diameter and 3000 m chimney diameter can generate  $1.67 \times 10^8$  kW hr in some locations in Egypt. Olusola Olorunfemi, Bamisile [13] done the review of solar chimney technology in Desert Prone Villages of Nigeria. He found that the cost of setting of solar chimney power plant is same as the cost of laying electrical cables in the villages which is located 200 km from the nearest source of electricity. He also concluded that the low efficiency of this technology is also a major setback for this technology. Lot of research is required is required to use this technology more effectively.

## III. CLIMATE PARAMETERS AND LOCATIONS CONSIDERED FOR STUDY

### A) Climate Parameters

The effect of weather parameters may vary from location to locations. The weathers parameters which are considered for their effect on solar chimney performance are described in brief.

#### a) Isolation:

The intensity of sun varies from place to place during hole year according to the seasonal changes on the earth. The solar radiation received by the earth surface for the incoming solar radiation is known as insolation. It is the main source of energy on our earth planet. The variations during particular season are due to isolation. The variation in solar isolation is due to two major phenomenon that are the duration of daylight and the angle of the sun rays. The amount of daylight affect the duration of solar radiation and the sun rays angle directly affect the intensity of solar radiation received.

Clear days:

The monthly average of the number of days an average cloud cover less than 10% during a given month.

**b) Wind Speed:** Wind speed of wind flow velocity is a fundamental atmospheric rate .It is caused by movement of air moving from high pressure to low pressure .Wind speed can be measure by anemometer. Pressure gradient and local weather conditions are responsible for wind speed

#### c) Minimum Isolation:

It is the minimum value of solar radiation received by the earth surface. If the Sun is 45<sup>0</sup>above the horizon, the incoming isolation strikes the earth's surface. The minimum value of isolation received during December days

#### d) Atmospheric Pressure:

Atmospheric pressure, sometimes also called barometric pressure, is the pressure exerted by the weight of air in the atmosphere of Earth. In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point.

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**e) Relative Humidity:**

Relative humidity is the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at the same temperature. Relative humidity depends on temperature and the pressure of the system of interest. It is also defined as the amount of moisture in the air compared to what the air can "hold" at that temperature. When the air can't "hold" all the moisture, then it condenses as dew.

**f) Normal Radiation:**

It is a radiation dose rate at a specified location which is generated by any combination of natural and artificial ionizing radiation sources. However, in certain circumstances, such as in protection metrology, it does not include radiation from a specified source [14].

**B) Various Locations use for study**

The solar chimney prototype was tested in central region of India. The location was Amravati the region of Maharashtra .In these region there is Sun light almost nine months of the year but still there is scarcity of electricity in summer season. There is a Load shading of 9 to 12 hours in most villages of this region.

The experimental study is carried out as a part of PhD work. The comparison is made between three cities of Maharashtra that are Amravati, Pune and Kolhapur. For doing the study data is taken from NASA website [15]. 22-years average is take from Jul 1983 – Jun 2005.

**Table:1**

City	Latitude	Longitude	Elevation(m)	Western Boundary	Northern Boundary	Eastern Boundary	South Boundary
Amravati	20.5	77.5	401	77	21	78	20
Pune	18.5	73.5	389	73	19	74	18
Kolhapur	16.5	74.5	458	74	17	75	16

## IV. RESULT AND DISCUSSION

The weather parameters which are taken from NASA website with respect to months of year with 22 years average for three cities Amravati ,Pune and Kolhapur are plotted and following results are drawn.

**1) Isolation Vs months of the year**

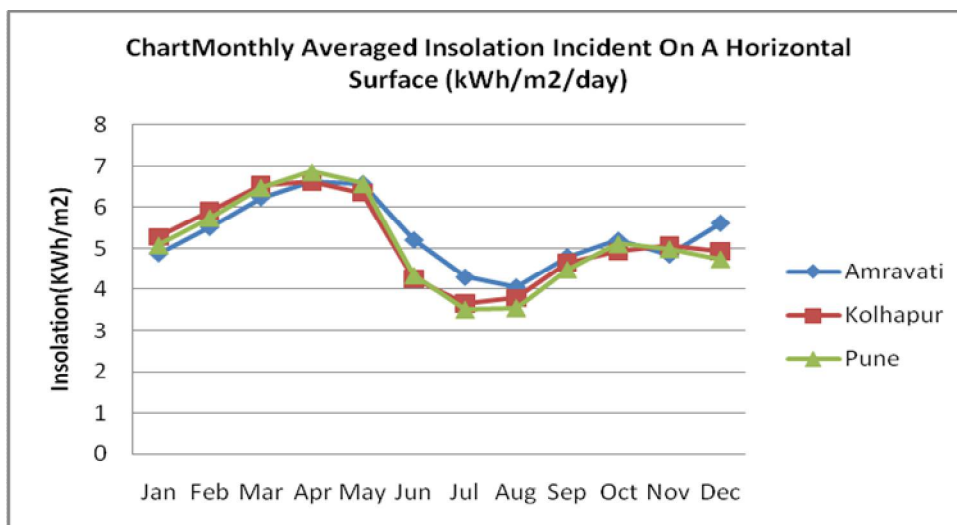


Fig. 2 Monthly Averaged Isolation Incident on a Horizontal Surface (kWh/m<sup>2</sup>/day)

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From fig.2 it is found that Amravati recorded maximum isolation as compared to other cities in the month of January and February it has lesser insolation but remaining months of the year it has high isolation.

## 2) Monthly Average Clear Days Vs Months of year

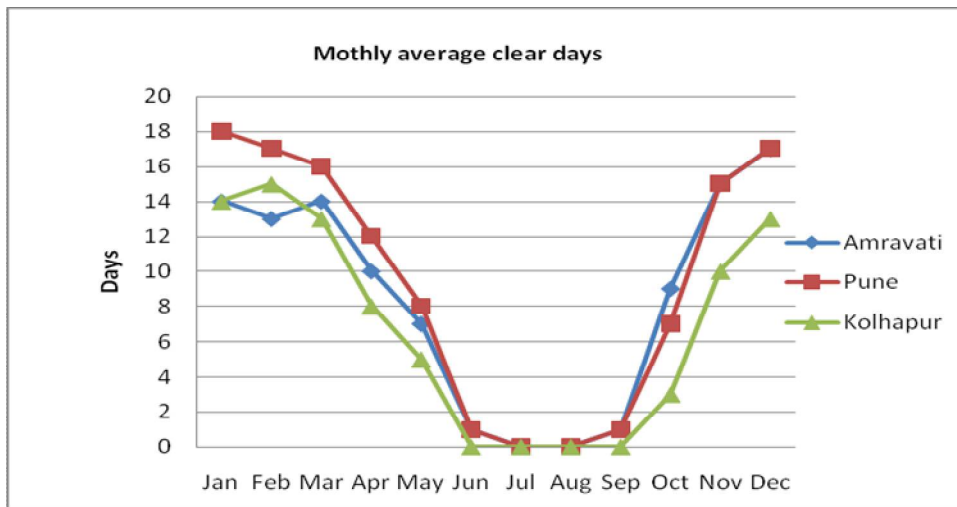


Fig. 3. Monthly Average Clear Days

From fig. 3 it is observed that Pune recorded more clear days throughout the year as compared to other two cities. Amravati recorded lesser number of clear days.

## 4) Monthly Average wind speed Vs months of year

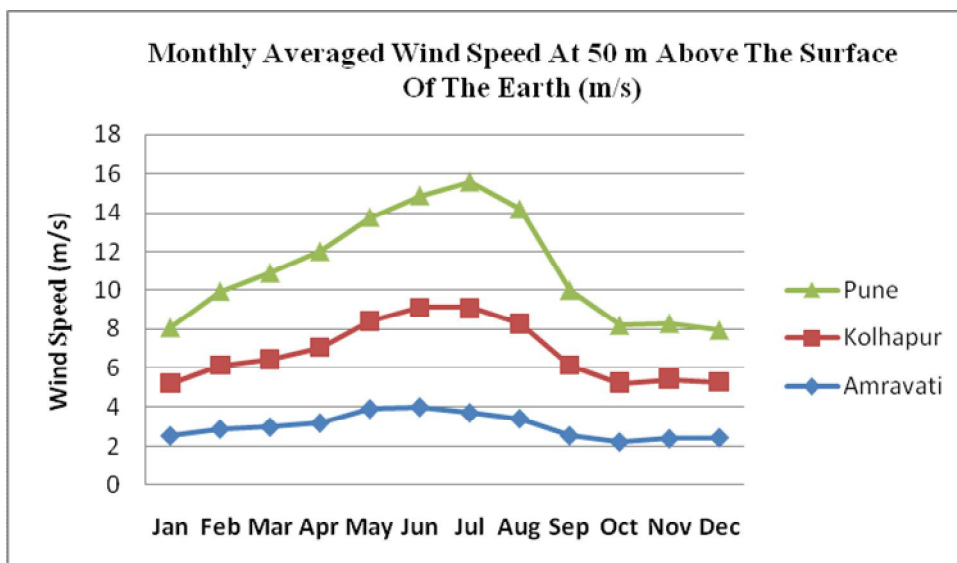


Fig. 4 Monthly Averaged Wind Speed at 50 m above the Surface of the Earth (m/s)

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From fig. 4 it is found that that Pune has recorded maximum wind speed as compared to other two cities. Amravati has lesser wind speed among them.

### 5) Minimum Available Isolation Vs months of the year

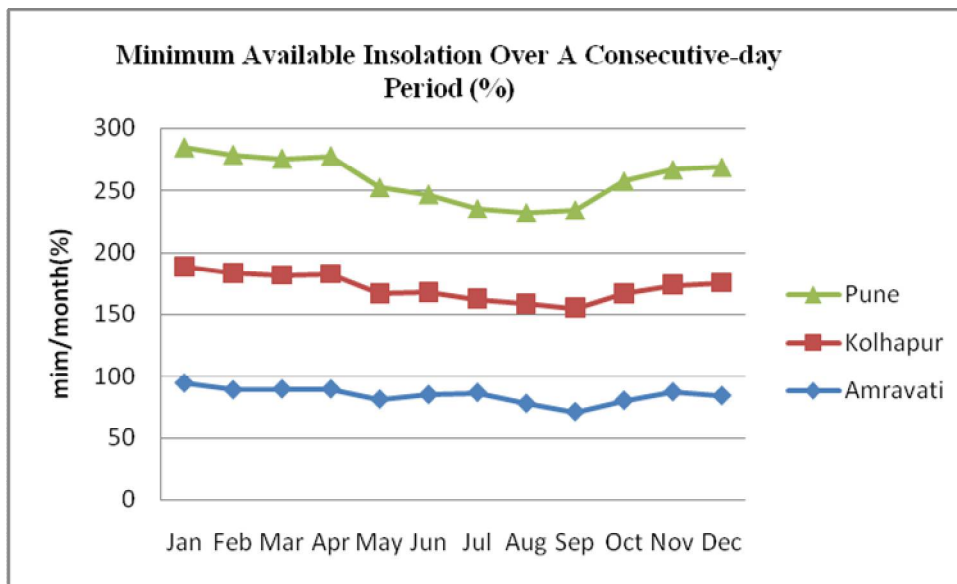


Fig.5 Minimum Available Isolation over A Consecutive-Day Period (%)

Fig. 5 shows that Pune has maximum value of minimum isolation as compared to other two cities. Amravati has lesser number of minimum isolation.

### 6) Monthly Averaged Atmospheric Pressure Vs Months of year

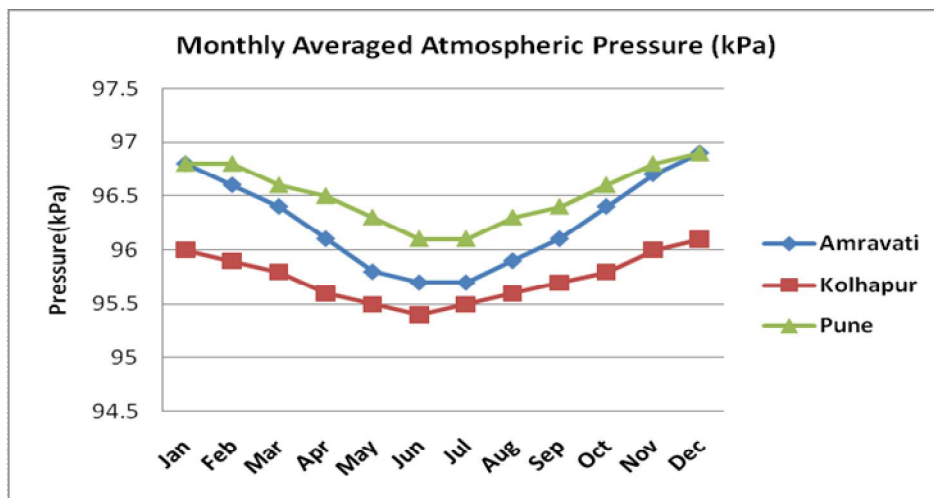


Fig. 6 Monthly Averaged Atmospheric Pressure

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From fig. 6 it is determine that Pune has recorded maximum monthly average pressure as compared to other two cities. Kolhapur recorded quantity of average pressure.

## 7) Monthly Averaged Relative Humidity Vs Months of year

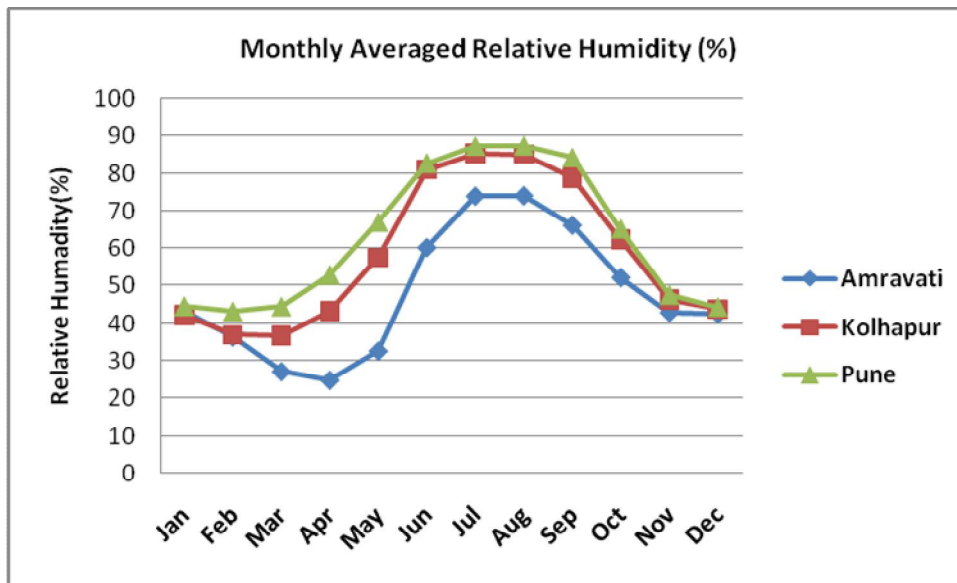


Fig. 7 Monthly Averaged Relative Humidity (%)

From Fig.7 it was found that Pune has more value of Average relative Humadity as compared to remaining two cities.Amravati has lesser humadity as compared to other two.

## 8) Monthly Averaged Direct Normal Radiation Vs months of year

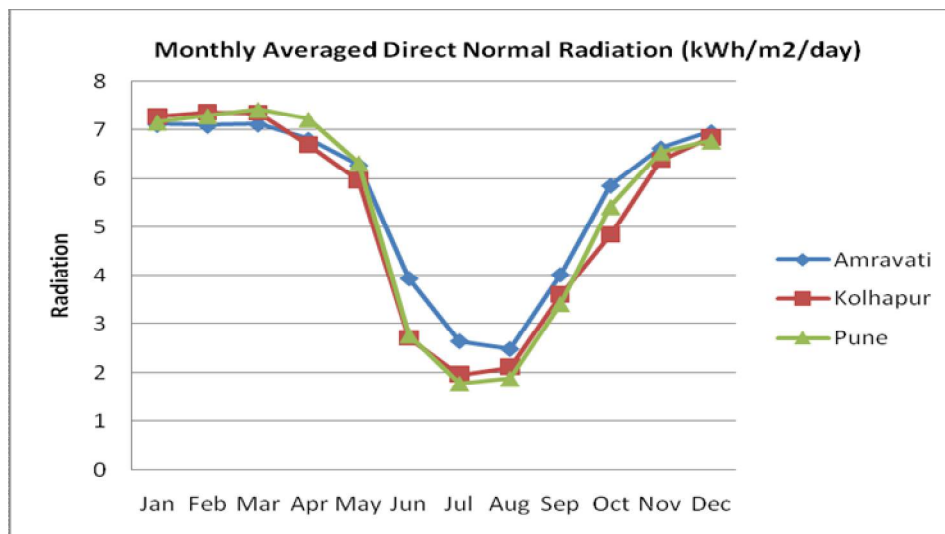


Fig. 8 Monthly Averaged Direct Normal Radiation

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From fig. 8 it was found that Amravati received maximum monthly average direct radiation as compare to other two cities. Pune has lesser normal radiation as compared to other two.

### V. CONCLUSION

There is a requirement to set up solar chimney power plant up to larger extent but for that it is required to study metrological parameters. The parameters mention in this paper are some of the few parameters of the large number of parameters responsible. Following conclusions are drawn after studying these parameters for three cities of India.

1) The Amravati City which has highest temperature in summer has highest value of direct normal radiation and Solar Isolation.

2) Some of metrological parameters like the monthly average relative humidity, monthly average atmospheric pressure, minimum average isolation, monthly average wind speed and monthly average clear days are higher value for Pune city.

3) Pune city has also the potential to setup solar chimney power plant along with Amravati because of higher value of some of the parameters among the studied parameters.

4) The possibility of setting solar chimney power plant varies from region to region and it depends on metrological parameters along with geometrical parameters.

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