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STUDY AND ANALYSIS OF INDOOR AIR QUALITY (IAQ) IN TEMPLES:

A CASE OF JYOTIBA TEMPLE, KOLHAPUR, INDIA.

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Abstract: Indoor Air Quality (IAQ) is an essential parameter of Indoor Environmental Quality (IEQ). IAQ impacts the health and efficiency of the occupants of the buildings. We can find wonderful built heritage in and around us, in India in abundance. Temples of a variety of gods and goddesses are worshipped by the lacs of Indian people. These are the living heritage of India. So many wonderful cultural rituals and traditions are followed today also. Jyotiba Temple is one of the main gods of most people of Maharashtra and the rest of India. Lacs of devotees from all parts of India visit this temple, so it is essential to study and analyze the quality of air inside, as it is a subject which is related to the health and comfort of lacs of devotees. The specific type of offerings is to the god Jyotiba. To measure the IAQ of the Jyotiba temple, objective and subjective measures are adopted for the measurements. The measurements are taken inside the temple at four locations using the calibrated equipment with time intervals of 2 hours in the three seasons of the year. The quantitative analysis of the collected data was done using XLSTAT's regression analysis tool, to obtain the relationship between different parameters. From the analysis of data of all the parameters of IEQ, it was concluded that the increased level of CO_2, $PM_{2.5}$, and decreased O_2 level as compared to the ISHRAE Standards 10001:2019 were observed; which creates poor IAQ conditions inside the temple.

Index terms: Indoor Air Quality (IAQ), Devotees, Jyotiba temple, O_2, CO_2, $Pm_{2.5}$, comfort.

1. Introduction

Indoor Air Quality (IAQ) is a major parameter of Indoor Environmental Quality (IEQ) which has a major impact on the health and efficiency of the building occupants. (Bean R,) India has thousands temples of variety deities; worshipped by lacs of devotees across India. Traditions and rituals are conducted by the devotees inside the temples. Most of the time people spend 80% to 90% time indoor; which is contaminated with harmful air concentration and hazardous to human health. (Frontczak M. et.al.2011) Due to pollution of indoor air many health issues are faces by the occupants; as irritation, coughing, sneezing, and headache. (Pilatowicz 1995). India has a great built heritage and living heritage attract lacs of people towards it in today's context also. (Hardy, A., (1995).

2. History of Jyotiba temple:

Jyotiba Temple is a very important Hindu Pilgrimage centre in southwest Maharashtra, dedicated to Lord Jyotiba; believed to be the rebirth of Brahma, Vishnu, Mahesh and Jamadagni. The re-incarnation was done to kill the demon Ratnasur. March and April are the best months to visit the temple, and many devotees visit during this period. (Kolhapur Municipal Corporation, 2016).Paugandrushi and Vimalaambuja have a divine son like a Jyoti (flame) named Jyotiba and Badrikedar as Jyotiba came to Kolhapur. Jyotiba and Mahalaxmi fought against the demon and made Karveer free from them. Mahalaxmi requested Jyotiba to stay and protect Karveer, so Jyotiba Idol is facing south, keeping an eye on Karveer. (Sarnaik S., 2000) The temple construction style is Hemadpanti. The temple is divided into three main parts *Garbha-gruha, Antarala, Sabha Mandapa*. The temple has five entrances. (Sarnaik S., 2000) *Chaitra Yatra* (Festival) is the biggest festival celebrated in Jyotiba. "*Jyotibachya Navane Changbhale*" is the punchline sung by all the devotees. *Gulal*, dry coconut, dates are thrown at the god on the temple, spire, and the palanquin of Jyotiba.

3. Indoor Air Quality (IAQ)

As per ASHRAE, the quality of air means the nature of conditioned or unconditioned air that is around us in the space which we occupy. Air pollution is the major environmental problem the world is facing today. Human beings spend around 90% of their time indoors. The indoor air is most of the time polluted due to harmful contaminants than the outdoor air (US EPA 2004). As per Robert Bean, Indoor Air Quality has the following parameters; O_2, CO_2, ozone, methane, sulfur dioxide, nitrogen dioxide, and particulate matter. The quality of the air hampers when the parameters of the air are not up to the standards. The air quality is good when a maximum number of occupants feel comfortable inside. (Pilatowicz G., 1995).

3.1 Oxygen (O_2):

Oxygen is essential for life and survival. The standard percentage of O_2 in the air is 20.9%. When the O_2 level drops below 19.5%, the air is O_2 deficient and affects health. (Rom. W., 1992).

3.2 Carbon dioxide (CO_2):

Carbon dioxide is a gas that is heavy, colourless, odourless and noncombustible. This gas is formed due to various burning activities and breathing activities. Plants absorb this gas during the daytime in the process of photosynthesis. The high CO2 level indicates the ventilation and air exchange problem of that space. (Kubba S.2010) A higher concentration of CO_2 indicated the poor quality of air. (Mui K.W., 2008).

3.3 CH_4:

It is a colourless, odourless and flammable gas present in the atmosphere; with the formula CH_4, one carbon item and four hydrogen items come together to form it. Agriculture activities, digestion process and wetland and sea are the primary source of methane emission (Seyfi S., Dursun S., 2011). Long term exposure to this gas is harmful to the health of the human being. (Zoric M. et al., 2019). 50 to 60 % of the gas is generated due to human activities and the digestion of organic matter (EPA, 2021).

3.4 Particulate matter ($PM_{2.5}$):

It is the primary factor of indoor air pollution due to human and natural activities. It remains in the air for a longer time, causing many diseases and is a significant concern to human health (Ki-HyunKim, Jan 2015). They are organic or inorganic, with sizes varying from 100/cm3 to 100000/cm3. Fly ash and another pollutant from various industrial and mining operations cause air pollution (EPA 1997). The primary source of air pollution in India is the burning of fossil fuels, vehicle emissions and construction activities (CPCB).

4. Need of the study:

The Jyotiba temple is important in Maharashtra, India; constructed hundreds of years before; it is visited and worshipped by lacs of devotees every year. The temple is overpopulated due to the devotee's presence from morning to evening, causing conjunction and overburden on the quality of the temple. Devotees get suffocated inside, causing many problems like irritation, cough, throat infection, discomfort. As it is a problem related to a large number of people is a cause of concern.

5. Aim and Objectives:

Aim:

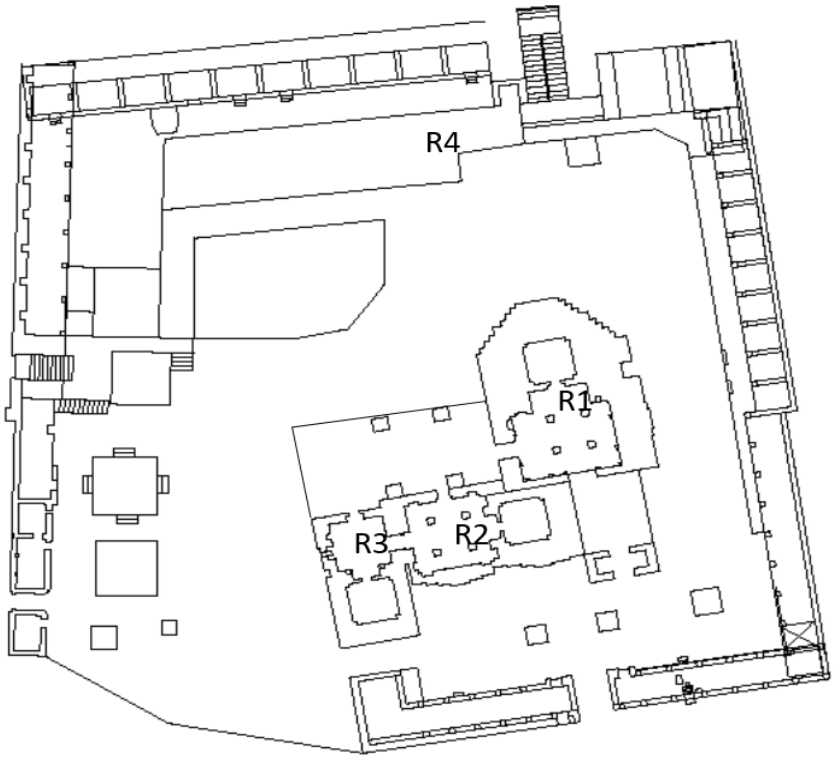
The main of the research is to study and analyze the air quality inside the Jyotiba Temple, which is situated in Maharashtra, India.

Objectives:

The objectives of the study to meet the goal of the research are as follows
1. To study and understand the issues related to IAQ inside Jyotiba Temple.
2. To collect the data of all IAQ parameters of the Temple Jyotiba.
3. To analyze the collected data
4. To conclude, based on the analysis done.

6. Methodology:

For the study and analysis of the IAQ of Jyotiba Temple, various methods like objective and subjective are adopted for the collection of the data. Based on ISO 16000-1, ISO-16000-32 standards and ISO 7730, the IAQ parameters are applied to collect the data. Data from the temple is collected in summer, monsoon and winter. The quantitative data is collected using calibrated instruments. The measurements were taken at the time interval of 2 hours during the day; at the selected four temple locations. R1- *Garbha gruha*, R2- *Dardhan mandapa*, R3- *Chopadai Devi chowk, R4- Outside the temple.*
For the measurements of the IAQ parameters, the Air Sensor- (Drager x-am 5600) and Mini Weather Station-(Kestrel) is used to collect the data from the five locations of the temples shown in the figure.



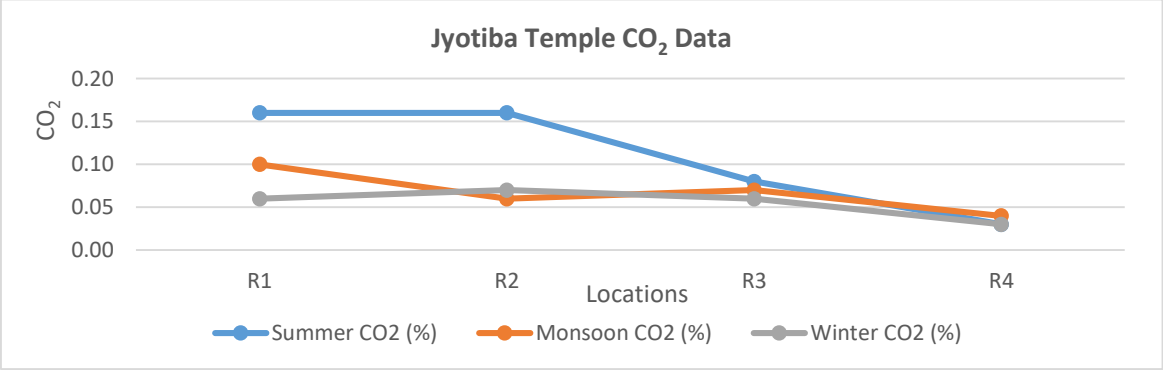
Source: Paschim Maharashtra devasthan Committee, Kolhapur.

7. Data Collection:

The quantitative data for the study of parameters of IAQ are collected from the temple throughout the year in summer, monsoon and summer. The time interval between two readings is 2 hours. The locations for the data collection were identified, and data were collected from the locations using the calibrated equipment. Data is tabulated and analyzed using the M.S. Excel worksheets.

8. Analysis and Discussion

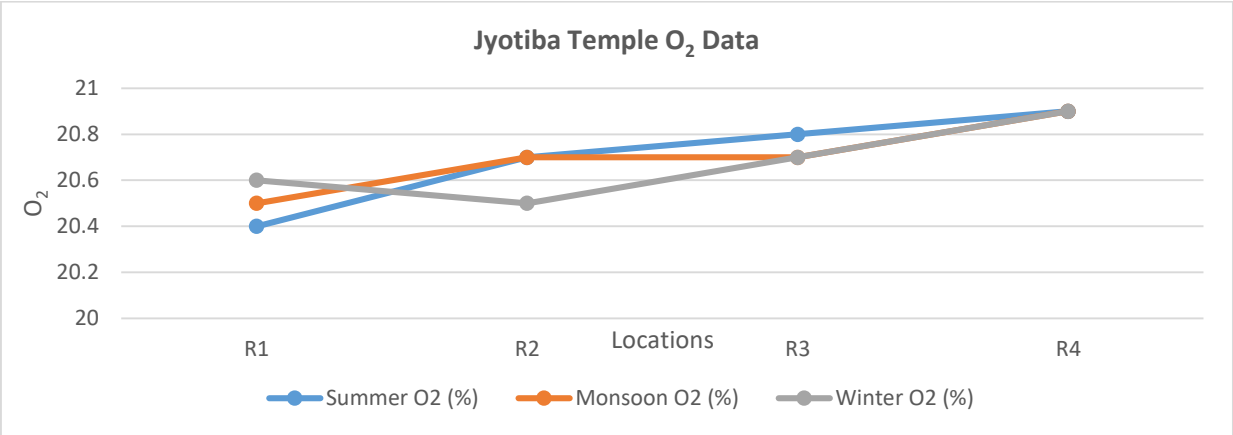
8.1 Analysis of CO_2 inside the temple.



Graph 1 analysis of CO_2 in Jyotiba Temple.

From graph no.1, it is clear that in summer, a higher concentration of CO_2 is observed at the R1 location, which is 0.16% and in monsoon, 0.10%. Outside the temple, at R4 location, the concentration of 0.03% is observed, which is within the limit of ISHRAE Standards1000-2019 (0.03%)

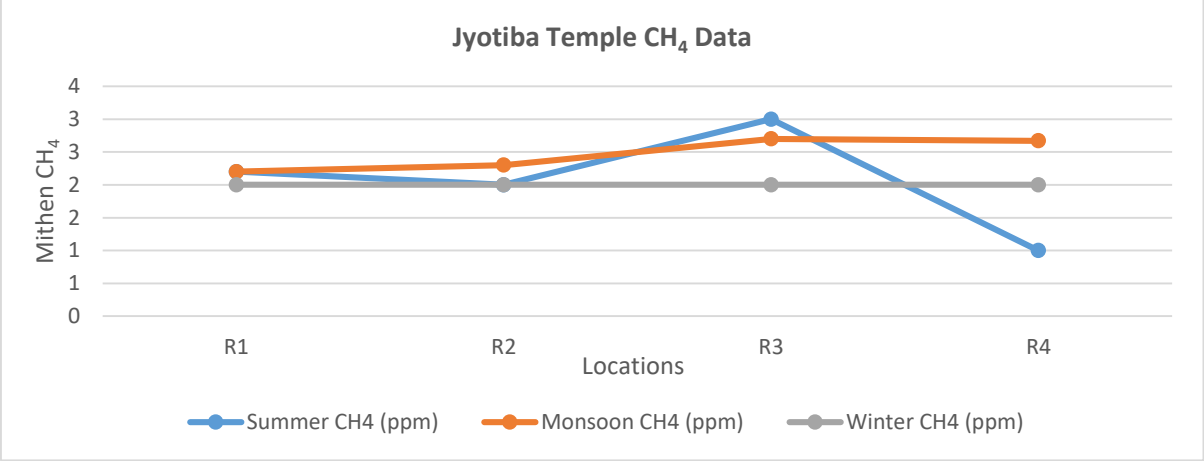
8.2 Analysis of O_2 inside the temple:



Graph 2 Analysis of O_2 in Jyotiba temple.

From graph no.2, it is clear that a lower concentration of oxygen is observed inside the temple at the R1 location and R2 location, respectively, in all seasons, which is 20.4% and 20.5%, respectively. Outside the temple, the oxygen concentration is 20.9%.

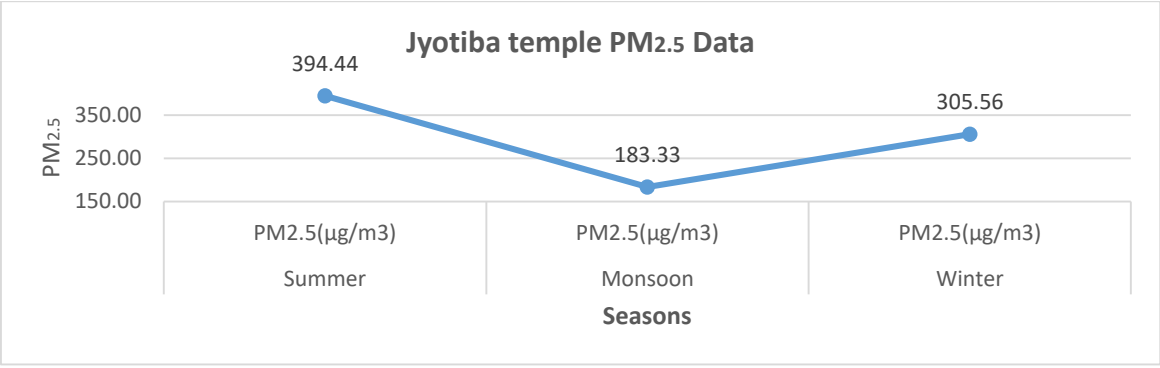
8.3 Analysis of CH_4 inside the temple:



Graph 3 Analysis of CH_4 in Jyotiba Temple

From graph no.3, it is clear that three ppm CH_4 is observed in summer and monsoon. There is no little increase in the CH_4 concentration is observed inside and outside air of the temple as compared to the ISHRAE Standards1000-2019 (2 ppm)

8.4 Analysis of $PM_{2.5}$ inside the temple:



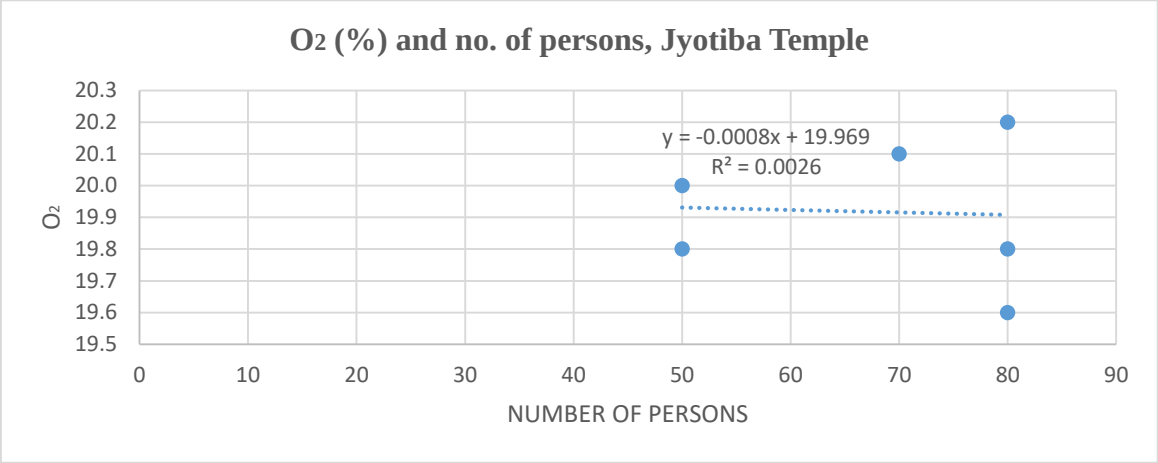
Graph 4 Analysis of $PM_{2.5}$ in Jyotiba Temple

From graph no. 4, it is clear that the value of $PM_{2.5}$ in the summer season is 3.94.44 µg/m3, which is higher, and in the winter season, it is 305.56 µg/m3, which is also on the higher side as compared to the ISHRAE standards 1000-2019. (15µg/m3). Monsoon has a 183.33 µg/m3 value of $PM_{2.5}$, which is less, as compared to the summer, is, but high as compared to ISHRAE Standards1000-2019. (Monitoring and Analysis were done with the help of the Department of Environmental Science Shivaji University, Kolhapur.)

9. Regression analysis of the readings-Jyotiba Temple

The regression analysis was done to identify the correlation coefficient between the parameters. The regression analysis was done for the number of persons and O_2 and CO_2.

9.1 Regression analysis of the readings-O_2 and number of persons

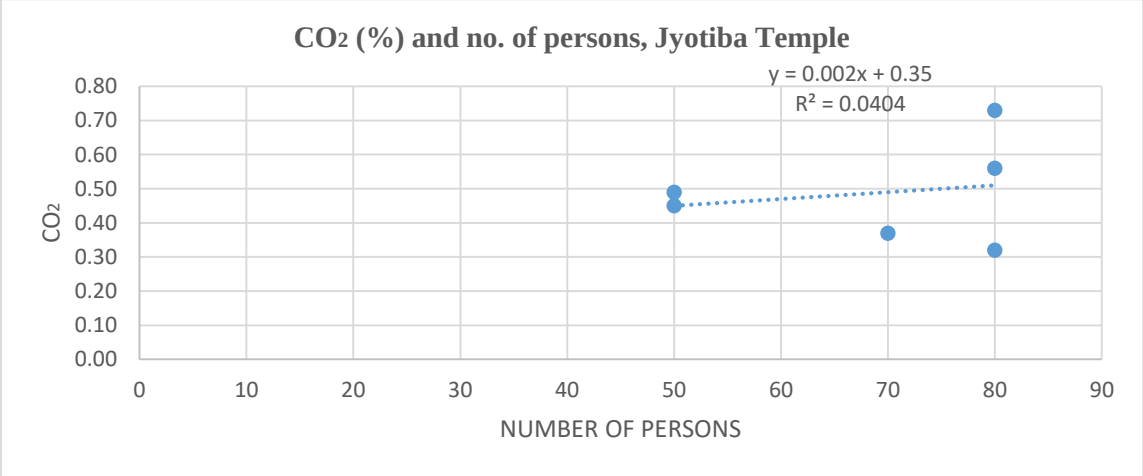


Graph 5 Regression analysis of the readings-O_2 and number of persons

From the above table, the regression analysis between No. of persons and O_2 represents that:

1. The correlation coefficient between the number of persons and oxygen is 0.05, which means a low degree of –ve correlation between them. It can also be concluded that if the number of a person increases, there will be a decline in the oxygen level.
2. The linear regression between the number of persons as 'x' and oxygen 'y' is obtained as Y=-0.0008x+19.969
3. The predicted value of O_2 is obtained from the linear regression is Y=19.89 % for the expected no. of persons x=100

9.2 Regression analysis of the readings-CO_2 and number of persons



Graph 6 Regression analysis of the readings-CO_2 and number of persons

From the above table, the regression analysis between No. of persons and CO_2 shows that:

1] The correlation coefficient between No. of persons and CO_2 is 0.201, which indicates there is a minor degree of positive correlation amongst them, i.e. it can be determined that if the number of a person increases, there will be an increase in the CO_2.

2] The linear regression between No. of persons(x) and CO_2 (y) is achieved as Y=0.365x+0.002

3] Hence the projected value of CO_2 is gained from the linear regression is Y = 0.55 % for the projected no. of persons x=100

10. Conclusion:

From the above analysis, it is clear that the concentration of CO_2 is increased inside the Jyotiba temple compared to ISHRAE standards 1000-2019. A lower concentration of O_2 is observed inside the temple than the standards; due to the increased number of devotees visiting the temple and less cross ventilation. There is no specific increase in the values of CH_4 was observed. The value of $PM_{2.5}$ is very much higher than the standards of ISHRAE inside the Jyotiba Temple. More devotees are confined in the small space of the *Darshan mandapa* of the Jyotiba temple leading to poor Indoor Air Quality. The offering to god Jyotiba is *Gulal*; which is offered to god and throne on the temple, and air leads to an increase in the value of $PM_{2.5}$. So the overall Indoor Air Quality parameters are not

up to standards creating poor IAQ conditions inside the temple of Jyotiba, which may hamper the health of the visiting devotees. It can be determined that if the number of people increases, there will be a decrease in the O_2, and the projected value of O_2 is 19.89 %. It can be concluded that if the number of the person increases, there will be a rise in the CO_2, and the predicted value of CO_2 is 0.55 %

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