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Traffic related air pollution with particulate matter, sulfur pollutant and carbon monoxide levels near NH-44 in India

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Abstract. For the past two decades, the quality of air has been deteriorating. It is indeed a great threat to the environment. The primary source of air pollution is vehicular emission in urban areas. Hence air quality monitoring and assessment are required to understand the level of pollution and for its remedial measure. Here, air quality has been measured at three locations (Govardhan Intersection, GLA University and K.D. Hospital) besides National Highway 44, near Mathura City, India. Average weekly concentration of PM2.5, PM10, CO and SO_2 were 1231.72 μg/m^3, 1860.43 μg/m^3, 7.43 mg/m^3 and 48.93 μg/m^3, respectively near Mathura city. Higher concentrations of PM2.5 and PM10 were obtained due to heavy heterogeneous traffic. The increment in the PM2.5 and PM10 concentration level results in cardio-vascular, cardio-pulmonary and respiratory diseases. These diseases will affect human beings for a long-term syndrome. Technique for order performance by similarity to ideal solution (TOPSIS) method is used to rank the sampling locations based on their pollution level and found that Govardhan Intersection obtained the maximum value in terms of pollutant concentrations on a weekly basis. This research will be helpful in the management of air pollution as Mathura is a high-demand tourism center.

Keywords. Air pollution; human health; PM2.5 and PM10; sulfur dioxide; carbon monoxide; cardiovascular; cardiopulmonary diseases.

1. Introduction

Air contamination contributed to a significant worry in recent decades, with severe toxicological implications on human well-being and the environmental atmosphere. Air pollution has caused a significant impact on the human health as per the world health organization (WHO). They are harmful not only on biotic but also on abiotic resulting in air pollution. As per today's scenario in this growing world, every country is developing in terms of technologies such as new types of construction, new factories and new vehicles trending every year. Emissions of industrial and transport along with the domestic consumption of low-grade fuels, result is an intense smoky atmosphere. In which transportation is the topmost source of air pollution [1], as they emit high number of pollutants into the air on a daily basis. The average growth rate of 9.2% was recorded by Indian motor vehicles sales updated monthly [2]. Higher concentration of air pollution has been faced by 79.8% of the Individuals living in urban estate.

Population living in urban areas are vulnerable to air contamination due to increased urbanization and industrialization which exceed the guidelines of the WHO [3]. The problem of air pollution posed by transport has also become acute because vehicles contaminate the environment by releasing toxic elements like carbon monoxide, sulfur dioxides and particulates matter that are very injurious to health [4–6].

Due to air pollutant emissions, the globe faces a great challenge of long-term syndrome diseases such as asthma, respiratory problems, pregnancy complications and heart diseases [7]. Air pollution due to heavy traffic causes lack of cognitive function as observed via epidemiology studies [8]. It also causes various heart diseases which can result in heart failures by limiting the oxygen to reach heart organs and other acute coronary patterns that are life-threatening for the human if they try aggressive physical activities, anxiety and other caffeine products or alcoholic beverages that trigger structural defect [9]. Despite the fact that a small group of people have the probability of developing myocardial infraction (MI), there is a debate on the of role of the air pollutants in contaminating the environment that induces MI, as the very small increase in individual's risk for developing MI, the impact of air pollution on a population has taken the center stage as majority of individuals are visible to it [10].

India is struggling to keep urban air emission standards under WHO guidelines [11]. When people travel during the

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peak hours, they are exposed to traffic related air pollution (TRAPs) at a high rate [12]. A few research identified that even if the duration of travel is short, the commutants may get an increased percentage of their daily dose of air-related traffic pollution. High proportion of air impurities has direct relationship with the cardiological disorders and ventilator diseases in human beings [13–16].

There are many ways to assess the quality of air such as multi-criteria decision analysis [17], fuzzy multiple attribute decision [18], and neural network [19] and air quality index (AQI) [20]. The air quality index (AQI) asses in the Mediterranean area from 2013- 2015. The AQI reflects simply and plausibly the air quality level, it neither considers the correlation between multiple pollutants nor provides the decision makers with proper suggestions [20]. A hybrid algorithm joins the genetic algorithm, fuzzy theory and neural network to assess air quality. Subjective factors affect the fuzzy decision, hence no accurate evaluation is done by this method [21]. Though numerous studies have been conducted on air quality [22–25] and they are unable to provide effective information for managers to control air pollution ahead. A set of comprehensive air quality evaluation methods is necessary to help managers how to control air pollution.

Study expresses the level of air pollutants using the relative entropy theory and the technique for order preference by similarity to ideal solution (TOPSIS) approach. Usage of weight air contamination to entropy has emerged as a helpful technique known as entropy-based weighting [26]. TOPSIS method is an efficient approach for evaluating the euclidean distances between many potential solutions in order to determine their choice of order by the resemblance to a model approach. Management can utilize the results to make better decisions about air pollution control using positive model approach as well as negated approach for challenging encounters with multiple objectives. TOPSIS is used to compute the amount of air pollutants involved in air quality index [27]. Therefore, the TOPSIS technique is required to provide an overall rating of the locations, taking into account short-term and long-term chronic disorders, and prioritizing judgements in the event of eventualities.

The key intent of this paper is to compute the concentration of air impurities in Mathura city and to study the influence of air contamination on human beings. Mathura is one of the biggest pilgrim centers in India as more than thousands of pilgrims travel to Mathura on daily basis. The ultimate cause of air pollution is due to floating vehicles at Mathura city. The collected data of air pollutants criteria limit is monitored on the basis of the standard given by the centre pollution control board (CPCB). This will help the Indian authorities to control and preserve the environmental state and community well-being in Mathura city, India.

2. Materials and methods

2.1 *Study location*

The busiest highway connecting New Delhi and Calcutta is National Highway-19 (NH-19) that run through four states viz. Bihar, Uttar Pradesh, West Bengal and Jharkhand. It has a length of 1269.7 Kms and represents a major share of historic Grand Trunk Road. Delhi to Agra route is called as national highway-44 after the renumbering of national highways. The traffic volume of the highway segment between New Delhi to Agra is particularly higher due to the high number of tourists in Agra, Mathura and Vrindavan. The Mathura and Vrindavan is famous because of great cultural importance and great antiquity. Moreover, Agra is famous for Taj Mahal which is one of the Seven Wonders of the World. It is located approximately 57.6 kilometers (35.8 mile) to the north of Agra, and 166 kilometers (103 mile) to the south-east of Delhi and positioned at 27.28°N 77.41°E. It has an average raise of 173.6 meters. Mathura district is 3340km^2 in area of which 15.92 hectares are under the ownership of the Forest Department. The soil types in this area include silty soil, sandy soil, and loamy soil and average rainfall in the district is 826 mm. The estimated population is nearly about 2,951,167 lakhs [28]. The average humidity in Mathura is 64%. This particular highway road is selected because it is over crowded with floating vehicles. Furthermore, this NH-44 bridges the two major cities that is Agra and New Delhi where Mathura and Vrindavan is the intermediate city. The study area is confined to the highway segment between Delhi and Agra. To determine the appropriate places, a survey was done before sampling. Govardhan Intersection, GLA University, and K.D. Hospital were chosen based on the survey that was performed. The key justification for choosing Govardhan Intersection was that it is a well-known and significant intersection due to heavy traffic floating from here in the Mathura and it comes under the commercial and residential zone, while GLA University and K.D. Hospital falls under silence zone. The air pollutant measurement devices were kept near the National highway. The recording time persisted for a week in November 2021.

2.2 *Physical Measurements*

The calibration of measuring instruments was regulated at the Environmental Laboratory in GLA University, Mathura, India.

(i) Dust sampler APM460 BL was used to collect PM10 and PM2.5 pollutants and the device was manufactured in India. The flow rate is 0.9-1.4 m^3/min free flow.
(ii) Gaseous Sampler APM433 was used to collect SO_2 air pollutants sample.

(iii) Spectrophotometer (UV-1800-240V) was used to compute the level of concentration.

(iv) Carbon Monoxide Meter CO-01 was used which measured CO Pollutant and the device comprises a precise and highly accurate sensors (steady electrochemical gas specific), that has efficient response time and precise calculation under a wide range from 0 to 1200 parts per million (ppm). The correctness of the instrument is ± 10 ppm. The dimensional resolution of the instrument is 1.1 ppm.

2.3 *TOPSIS Method*

Yoon and Hwang proposed TOPSIS, a multi-criteria decision-making approach [29]. According to TOPSIS, a geometric point's distance from a given alternative's distance from the optimal solution is measured in terms of the Euclidean distance. This distance must be as short as possible and as close as probable from the model answer. A positive model formulation of the solution can be achieved by summarizing the best values of each feature. To arrive at a negative ideal solution for each attribute, the worst values are added together. Because the optimal solution is closer, TOPSIS takes it into account when calculating distances to alternative solutions. The decision-making process is commonly completed in this manner. This is due to the fact that the concept is basic, easy to comprehend, efficient computation, and has the capacity to quantify the relative performance of the alternative decisions. When assigning values to air quality parameters, entropy-based weights have emerged as a useful method. The author analyzed and evaluated the data for air quality issues in the cities of China by using TOPSIS method and derive the thermodynamic diagram of air quality [26]. The author evaluating air pollution that takes into account multiple criteria at once. In order to evaluate air quality in Vilnius, Lithuania, the TOPSIS method was used [30]. The author discusses an investigation into the use of the SOAR and PESTLE frameworks for air pollution in Mashhad, Iran, which included interviews with city officials and a survey of residents. The method ranks approaches favorably according to how closely they resemble the optimal solution using TOPSIS method [31]. TOPSIS method is based on the idea that the geometric distance of preferred alternative should be minimum from ideal solution and maximum from the non-ideal solution. Following steps are given:

Steps for calculating the TOPSIS method

a. Finite set of $m\ (\geq 2)$ alternatives: $K=\{k_i | i\ \varepsilon\ I\}$, where $I=\{1,2,\ldots\ldots,m\}$
b. Fixed set of criteria: $R=\{R_j |\ j\ \varepsilon\ J\}$, where $J=\{1,2,\ldots\ldots,n\}$
c. The weight vector of the criteria: $L=(l_1, l_2,\ldots..,l_n)$ such that $Lj>0$ *and* $\sum_{j=1}^{n} lj=1$

Decision matrix has the evaluations summary as below:

$$A=\begin{matrix} k_1 \\ k_2 \\ \cdots \\ k_m \end{matrix}\begin{bmatrix} r_{11} & r_{12} & r_{13}\ldots.. & r_{1n} \\ r_{21} & r_{22} & r_{23}\ldots.. & r_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ r_{m1} & r_{m2} & r_{m3}\ldots.. & r_{mn} \end{bmatrix}$$

where r_{ij} represents the performance degree of the k_i against the criteria R_j.

TOPSIS can rank the substitutions by using the following steps mentioned in the above information:

I. Decision Matrix Normalization

$$\overline{d_{ij}}=\frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \quad (1)$$

II. The weighted normalized decision matrix $E=(e_{ij})_{m*n}$ is computed as follows based on the computation of weighted normalized decision matrix:

$$e_{ij}=l_j * d_{ij} \quad (2)$$

III. Determining the Positive and Negative model formulation of solution matrix:

$$PIS=\left(e_1^+, e_2^+, \ldots, e_n^+\right)=((\max\ e_{ij} : j \in G') \quad (3)$$

$$NIS=\left(e_1^-, e_2^-, \ldots, e_n^-\right)=((\min e_{ij} : j \in G') \quad (4)$$

where G' represents the set of benefit criteria.

IV. Computation of separation measures based on the n-dimensional Euclidean distance.

$$S_i^+=\left[\sum_{j=1}^{m}\left(e_{ij}-e_j^+\right)^2\right]^{0.5} \quad (5)$$

Similarly, the separation measure from NIS is computed as follows:

$$S_i^-=\left[\sum_{j=1}^{m}\left(e_{ij}-e_j^-\right)^2\right]^{0.5} \quad (6)$$

Computation of performance score to the ideal solutions.

$$P_i^+=\frac{S_i^-}{S_i^+ + S_i^-} \quad (7)$$

Based on performance score alternatives are ranked. The maximum value of performance score makes the better rank of the alternative.

3. Result and discussion

3.1 *Particulate matter*

The Production proportion of highways and any other road particles PM2.5 and PM10 is the role of heaviness of the

automobile, also if the roads are properly surfaced with cement or it uneven with not surfacing with cement. Our data collection spanned from November 2020, and was carried out over 7 days. The range was as picked up as it hovers the wide array of PM2.5 and PM10 mixtures, that were very high in November because people in India celebrates Diwali with ultimate pomp and glamour in this month. On top of this, the selection was also made on the observation of having less rainfall during the month which eases the data collection. Dust sampler apparatus was selected for PM2.5 and PM10. Thus, ambient PM2.5 and PM10 concentrations were recorded for 24 hours of the road tours. Health of the human is significantly impacted by the Particulate Matter concentration in the fresh ecological air. It was also observed that on weekend's concentration level of PM2.5 and PM10 raised to significantly high numbers crossing the threshold of CPCB standards as showcased in Figures 1 and 2 impacting human health. When the proportion of PM2.5 and PM10 is raised in the air, it causes cardio-vascular disease, cardio-pulmonary disease, and respiratory diseases. Many scholars, scientist, investigators have identified a direct association among air pollution and respirational disorders in human beings [14–16]. Pollutants like particulate matters PM2.5 and PM10 are recorded because it is the most benchmark of ambient air contamination and associated with many health hazards in the long-term syndrome diseases [30–32]. Fossil fuel emits coarse particulate matters called PM2.5 and PM10 when burned in internal ignition engines and such flames are found in vehicle exhaust [33]. penetrating deep inside the respiratory system and traverse across human body via blood vessels [34]. The process to emit the ultrafine particles gets initiated when fossil fuels that contains Sulphur gets oxidized to sulfuric acid which gair and gets diluted there. These Contaminated particles get absorbed by Sulfuric acid then turns out to be the nuclei of the large molecular particles which get condensed [8, 35–37]. These criteria air pollutants are monitored and measured on continuous basis in many countries around the world [38–40]. As a fast evolving and emerging nation with a growing inhabitant, India is severely impacted by PM2.5 and PM10 pollutants, there are nine cities published with highest recorded air pollution in the world as reported by the WHO (WHO, 2016) [3]. Exposure to high levels of PM2.5 causes ~1 million premature mortality per year across India [41]. In order to tackle this PM2.5 and PM10 pollution, the Central Pollution Control Board (CPCB) of India has made amendments and improvements in their policies to mitigate the very concerning issue that world is facing and has revised the National Ambient Air Quality Standards (NAAQS) in 2009 that included PM2.5 and PM10 regulations (CPCB, 2009) [42–44]. Some mitigation policies have been implemented in major Indian cities but limited improvement in air quality (~10% reduction in PM2.5) has been seen [45–47].

3.2 *Particulate matter*

Currently the world especially the urban and developed cities are facing CO pollution which is a serious issue where the traffic concentration is high due to various reasons like air quality index, traffic volume, traffic increase and celestial and meteorological conditions. Ambient concentrations, in-vehicle levels, and individual contact to CO are usually progressive in emerging countries than in the established countries. This may have been caused by several factors including poor vehicle maintenance and deficient use of vehicle emission control systems. Figure 3 recorded CO impurity level throughout the daytime and night throughout for a week in the month of November 2020. The observed CO levels was under the CPCB limits which can be the resultant of many criteria such as goods

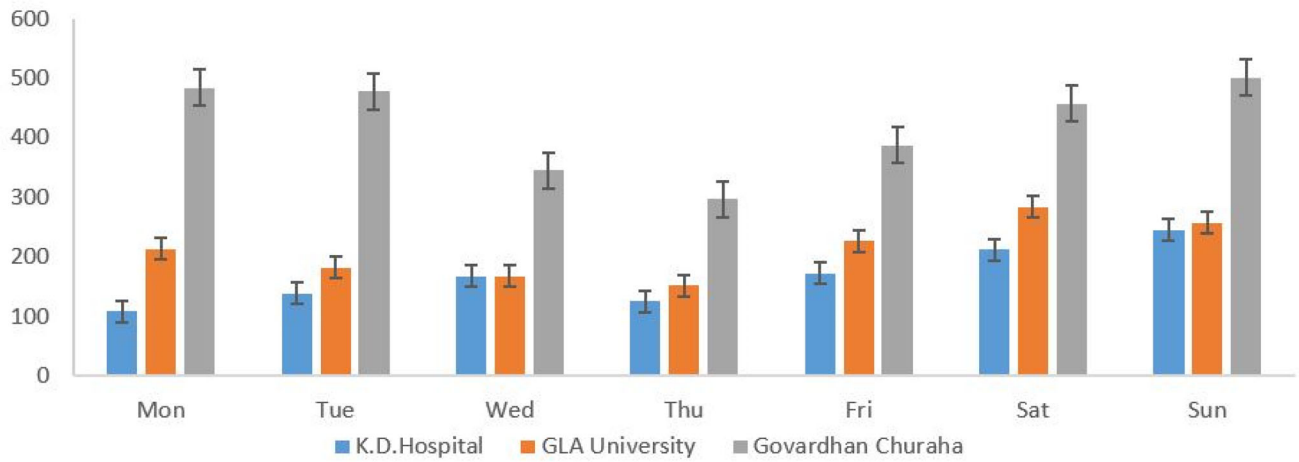


Figure 1. Weekly Variation Concentration of Pollutant PM10 (μg/m^3).

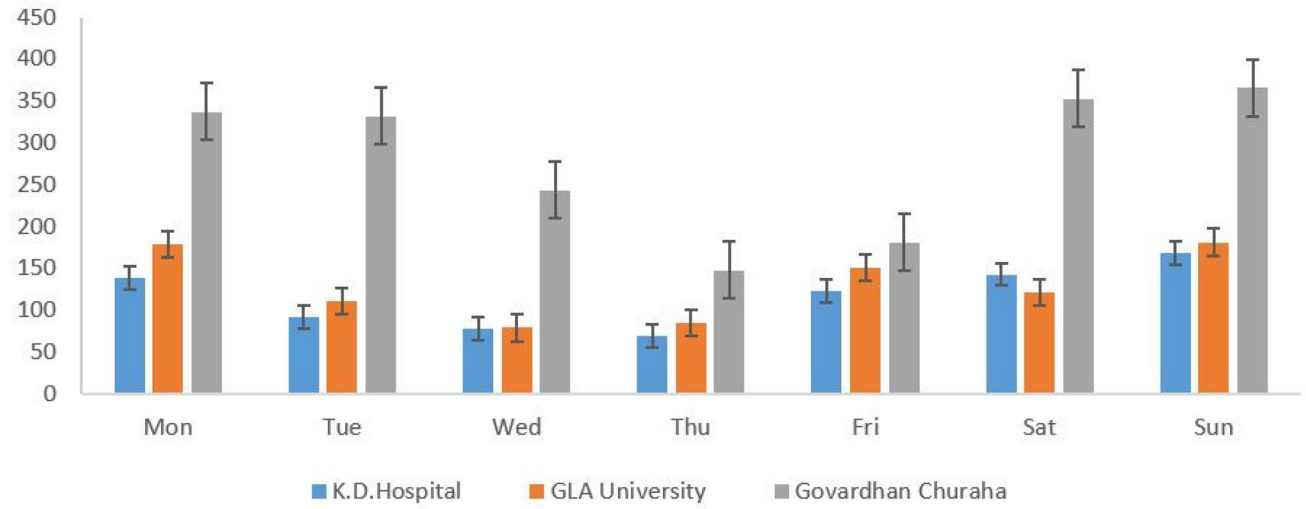


Figure 2. Weekly Variation Concentration of Pollutant PM2.5 (μg/m^3).

care. The typical CO concentration on working days is 0.93 pm and during the off hours 1.35 ppm.

However, it is estimated that the emission of carbon monoxide in the global environment will be 2650 million per tonnes, which is close to 60% from human actions and other 40% is contributed by global atmospheric process in which 15% of global greenhouse gas emissions is caused by transportation. These emissions are mainly resulting from combustion of natural gases, heavy loaded cargos, and petroleum products in engines [48]. The main source of CO and CO_2 emission is the automobiles, electronic gadgets that uses carbon-based energies. However, the vehicle cabin is a microenvironment with potentially high levels of carbon dioxide (CO_2). In cities, transportation and industries manufacturing the automobiles are identified as the key holder of the release of Carbon monoxide and carbon dioxide. High concentrations of carbon monoxide and carbon dioxide usually happen in zones with heavyweight stream of traffic force and congestion [49–52]. Although it is evident that CO threshold is well within the CPCB limits however it is important to take preventive measures to reduce or control the CO concentration measures.

3.3 *Sulfur Pollutant*

The largest production of SO_2 is the ignition of sulfur-having energies like petroleum products (coal and diesel), in the power plants, industrial, and transportation. Sulfur dioxide (SO_2) is one of its kind which mixed widely as a air pollutant [53]. The results provided in Figure 4 represent the measured concentration of SO_2 the average SO_2

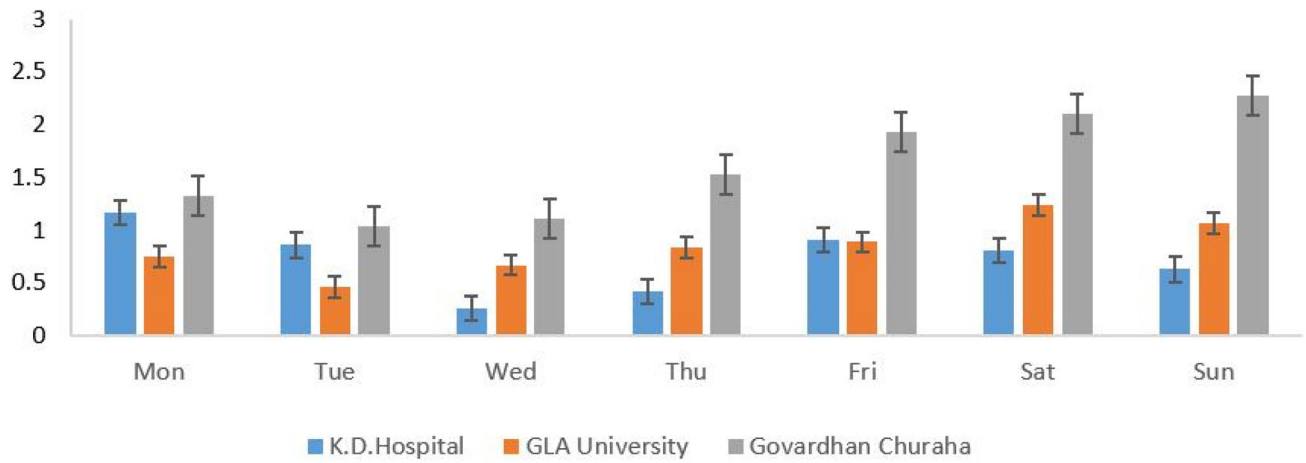


Figure 3. Weekly Variation Concentration of Pollutant CO (mg/m^3).

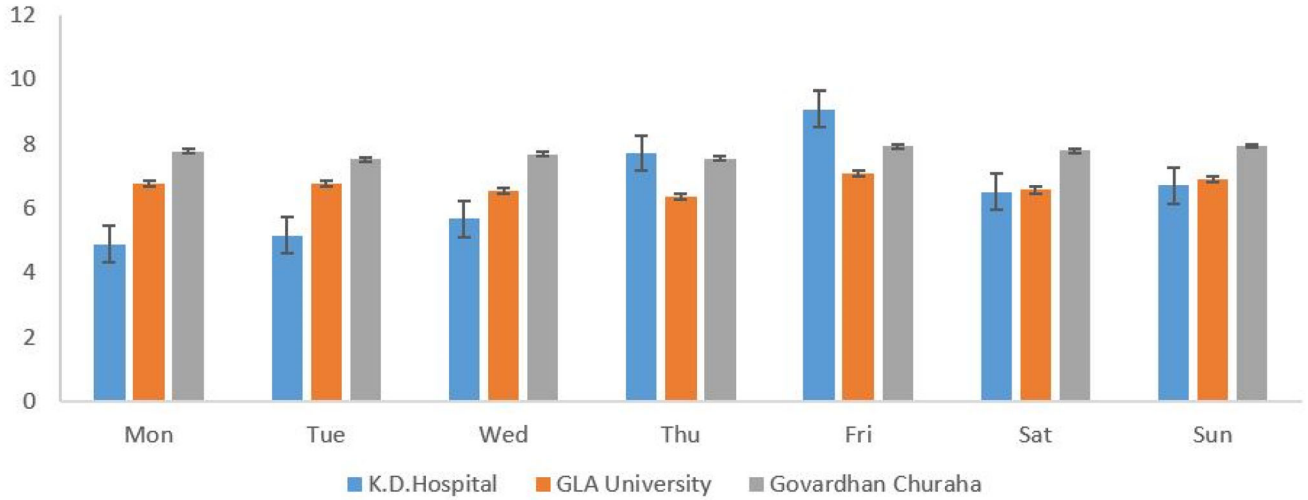
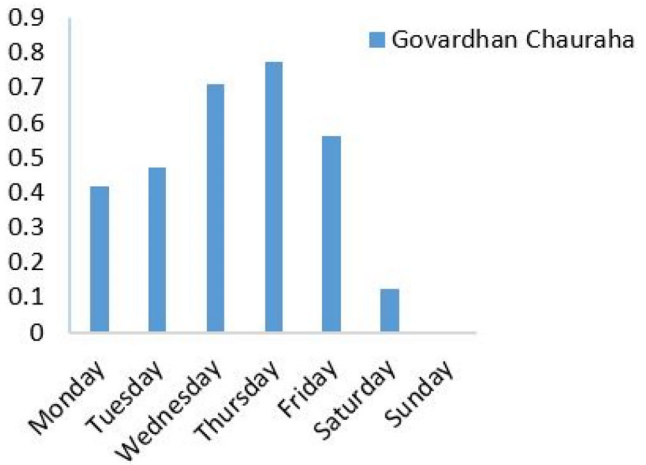
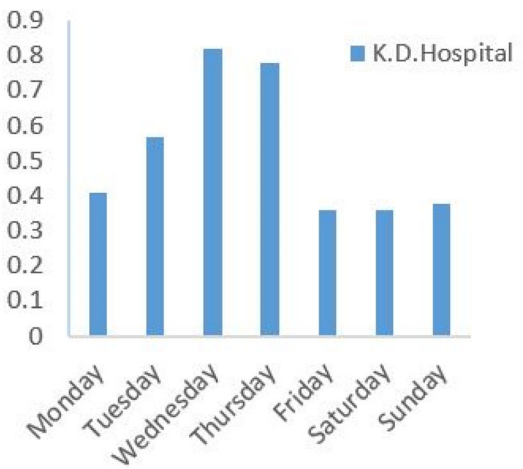


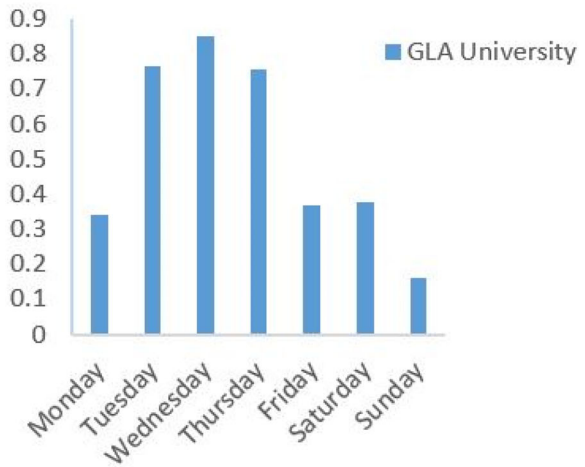
Figure 4. Weekly Variation Concentration of Pollutant SO_2 (μg/m^3).



(a)



(b)



(c)

Figure 5. Location-wise Performance score. **a** Govardhan Chauraha, **b** K.D.Hospital and **c** GLA University.

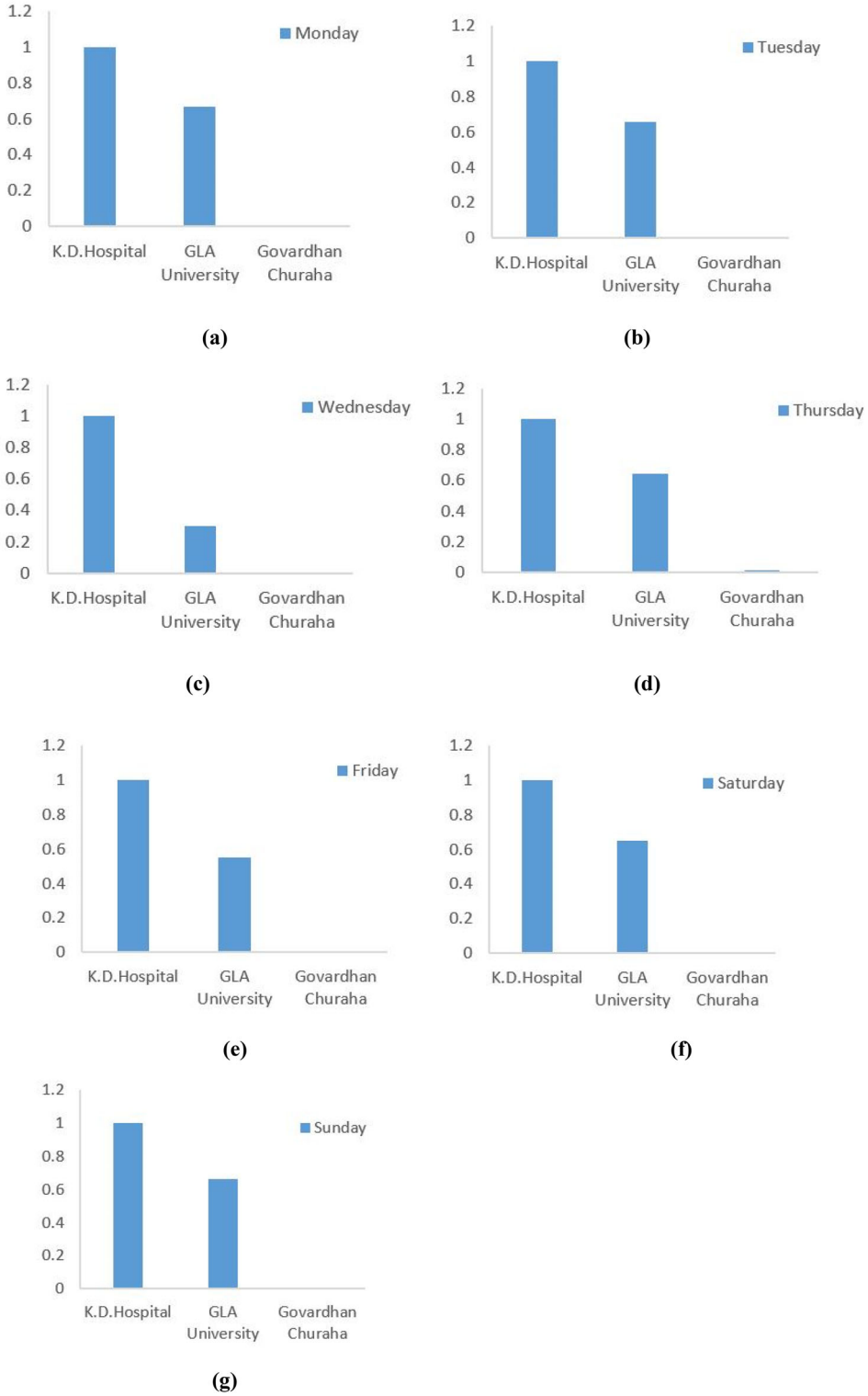


Figure 6. Per day performance score at Govardhan Chauraha, K.D.Hospital, and GLA University.

concentration on working days is 6.96 μg/m^3 and non-working days are 7.06 μg/m^3. Which not exceeded the CPCB limit, which represents no threat to community well-being and the environment. Indian fuel that contains elevated levels of sulfur can be considered as a fundamental reason for such concentrations. In Year 2019, India ranked 1st in emitting the human made SO_2 with 21% of world-wide having 5,953 kilotons, competing which Russia

ranked 2nd with 3.362 kt/year and china stands at third position which 2,1562 kt per annum emitted 21% of global anthropogenic (human-made) SO_2 emissions -or about 5,953 kilotons a year nearly double that of second-ranked global emitter, Russia at 3,362 kt/year. China occupied the third position at 2,156 kt per annum [54]. SO_2 can cause serious problems related to human health even when they are emitting in little quantities (ppm level) [55]. SO_2 main candidates are those who are suffering from asthma or have respiratory issues at a concentration of 0.51 ppm. Gas has different smell which makes it easier to be identified [56–59].

3.4 *TOPSIS*

The collected data was evaluated and analyzed on weekly performance score basis on three locations i.e., Govardhan Intersection, K.D. Hospital, and GLA University. Govardhan Intersection obtained worst performance score. This implies that level of PM2.5 and PM10, SO_2, CO are highly increased. The increased values of pollutants will lead to long term syndrome diseases such as cardiovascular, asthma so on. Also, Govardhan Intersection is surrounded by residential and commercial area. So, the chances of long-term syndrome diseases rise impacting the human life in that area (Fig. 5).

Whereas K.D Hospital obtained good value performance score. As K.D hospital includes large amount of vegetation in the surrounding premises. Therefore, it reducing the level of PM, SO_2, CO. However, GLA University obtained average value due to the large number of students and employees in the university. Lin *et al* 2021 using relative entropy theory and the iTOPSIS method (improved order preference by similarity to the ideal solution), a novel approach was proposed for conducting a comprehensive evaluation of air quality that takes into account multiple pollutants. Using these calculated total weights, the iTOPSIS method ranks the air quality. In the end, a case study is used to assess the efficiency of the proposed approach. The outcomes demonstrate that the proposed approach can not only directly express the air quality level, but also provide crucial and useful data for managers to use in their efforts to reduce air pollution [27].

The collected data was evaluated and analyzed on per day performance score basis on three locations i.e. Govardhan Intersection, K.D. Hospital, and GLA University (Fig. 6).

4. Conclusion

In this study, air pollutant of the GLA University, KD Hospital, and Govardhan Intersection in Mathura was assessed for its air quality sustainability. The conclusion derived from the study is presented below.

- In this study different parameters such as SO_2, CO, PM2.5 and PM10 used for analysis. In which it was found that the PM2.5 and PM10 pollutants concentrations were high and were at seriously concerning levels which can cause life-threatening hazards for the public, students studying in the university, tourist and travelers passing by for various other reasons.
- These air pollutants make this zone as actively vulnerable to smog which can cause much danger. Also, the levels of the PM2.5 and PM10 were colossal and alarming.
- In order to characterize sample locations, TOPSIS was used, which included all measurable parameters and computed an overall rating of the sampling locations based on their relative pollution levels. According to TOPSIS methodlocation performance score, Govardhan Intersection is more polluted. TOPSIS was found to be an effective method for determining decision priorities.

This study is related to monitoring and assessment of air quality of Mathura at different locations besides the highway. Thus, the authoritative and governmental decisions should be applied which are controlled by laws should have the benchmarking of outdoor air impurities emission. This will help to forecast the health index of the population and prepare action plan to reduce the air contamination.

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