International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

An Analytical Study on Air Quality of Some Historical and Cultural Cities in Uttar Pradesh (India) with Special Reference to the Environment and Human Health

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Abstract:
The rapid urbanization, different construction works and deforestation recently increased in some famous historical,cultural and religious cities in Uttar Pradesh due to higher population pressure. Thousands of pilgrims visit these cities every year by motor and other vehicles.The motor vehicle exhaust also plays a vital role to enhance the toxic gases and aerosol in the environment.Many toxic particles,molecules,toxic gasses, chemicals, dust particles, vehicle exhausts and microorganisms also help to increase deterioration in air quality. Some factors like particulate matter, sulphur di oxide,nitrogen oxide, carbon mono oxide, carbon di oxide in higher concentrations directly affect and change the air texture as well as air quality.Higher concentrations of these substancesare very injurious to the environment as well as living being including human.In present investigation a comparative study is done in between the residential and industrial/commercial area of five famous historical, cultural religious citiesof Uttar Pradesh i.e. Varanasi, Prayagraj, Mathura, Gorakhpur and Ayodhya.Four air quality parameters i.e., air quality index (AQI), SO2, NO2 and PM10 average annual concentrations have been taken for this analytical study.AQI (Air quality index)was found 2 to 4 times higher in residential area while 3-6 times higher in industrial/commercial area in comparison to normal AQI value (0-50) inall studied cities/area.The highest average annual AQI value was recorded (166.40microgram/m^3) in Saket Nagar residential ofVaranasiwhile 313.36 recorded in Geeda industrial area of Gorakhpur.The annual average of sulphur dioxide (SO_2) concentration found 26.46 (microgram/m3) and 26.12 (microgram/m3) in residential area Varanasi and Prayagrajrespectively which is slightly higher than the standard value (20microgram/m3). SO_2 concentrationrecorded higher almost in industrial areaof all cities. It was found highest in Geeda industrial area of Gorakhpur (49.70 microgram/m^3) in comparison to normal annual value (20 microgram/m^3). The annual average NO_2 concentration in residential area almost found below or equal to normal value but it was recorded more than 3 times (33.44microgram/m3) in Geeda industrial area of Gorakhpur. The particulate matter (PM10) concentration recorded very high in all residential as well as industrial/commercial area of all studied cities. The highest PM10 concentration198.47(microgram/m3) found in Saket Nagar residential area of Varanasi city which is about 20 times higher than the normal value(10 microgram/m^3).The

highest average annual concentration ofPM10 recorded 355.06 (microgram/m^3) in Geeda industrial area of Gorakhpur which is about 36 times higher than normal annual value. The increasing concentration of the studied factors adversely affecting the environment as well as human health in these cities. The long term or short-term exposure of these pollutants is responsible for increasing various pulmonary disease in these cities.

Key word: APCE (Air pollution control equipment), AQGs (Air quality guidelines), AQI (Air quality index), ESP (Electrostatic precipitators), FGD (Flue gas desulfurization), PM-Particulate matter.

Introduction: India is a culturally diverse country and there are very famous historical religious cities situated in Uttar Pradesh. Thousands of people visit these places every year. There are some basic needs of visitors like food, shelter, drinking water and pure air these should be provided to him. Among all the above components air quality is the very important and essential component of life which directly influence all the civilian as well as visitors. Air in atmosphere is a mixture of different gases (N2, O2, CO2 etc.), these gases are found in a proper ratio. The gaseous ratio remains almost fix in all the seasons.Any adverse change in atmospheric gaseous ratio or contamination of hazardous substances make air polluted. Air pollution has been a major concern due to its adverse effects on human health, weather and climate (Kan et.al,2012; Z.Li et.al.,2017; Anenberg et.al.,2022). Pollutedair is a common problem of almost all developing countries including India. Air quality in India progressively deteriorate due to unbalance and exploited use of natural resources. India is the world's eighth most polluted country in 2022 (World air quality report of The Swiss IQAir). Various pollutants contaminate air and are responsible for air pollution. These pollutants can be categorised intotwo groups i.e.(A) indoor pollutants (B)outdoor pollutants. The main sources of indoor air pollution are some building materials as asbestos, lead, tobacco smokes, kitchen fuels such as wood, coal, charcoal crop wasteswhile fossil fuel, carbon particles, metallic particles and toxic gases are considered as outdoor pollutants. Watson et al., (2015) reported that the main sources of outdoor pollutants are vehicle, industries, rapid construction work and thermal power plants etc. in urban area while air pollution in rural areas is mostly due to usages of biomass for cooking and dispose of crop residue by fire. Wei et.al., (2023) studied surface concentration of NO2, SO2 and CO during COVID 19 lockdown and found CO concentration recovered to its normal level within 34 days while surface SO2and NO2 rebounded more than 2 times slower due to more CO emissions from residents increased indoor cooking and atmospheric oxidation capacity. The particulate matter is the major concern of outdoor air pollution. For PM10, about 83 percent cities violate national ambient air quality standards for particulate matters (NAAQS). A study on particulate matter shows that PM (particle 2.5 & 10 micrometre) concentrations found ten (10) time higher than the WHO guideline in 48 percent cities in India (WHO air quality guideline level 2021).The exploited use of natural resources, various activities i.e., vehicular emissions, industrial waste, burning of fossil fuels, smoke from cooking, the civil sector, the residual part of crop burning, and power sector etc are among the biggest sources of air pollution in Uttar Pradesh. In India ¾ part of electricity production comes from fossil fuel basically coal, oil, and gas. Three thermal power stations are situated in Uttar Pradesh which produce about 6134MW electricity. The Coal based thermal power plants are considered as the major contributors to air pollution. It produces CO2, SO2 and particulate matters (PM) in 82%, 89% and 82% proportion respectively. Thermal power plants produce over 2.65 billion metric tonnes of carbon to the atmosphere per year and it is the main component of global warming. Any adverse atmospheric change

affects human health adversely. TERI, 2015 report on emission shows that industrial combustion contributes 49% of the PM10 emissions followed by residential sector (31%) and open burning in India. Karagulian et al., 2015 reported that percentage contribution of different anthropogenic sources shows that traffic or automobiles contributed 34% and 37% in PM10 and PM2.5 pollution load, respectively. Particulate matter (PM) with a diameter of <10 µm is released into the atmosphere along with potential toxic elements (PET) from brake wear, which includes brake lining and disc abrasion caused by grinding, volatilization and condensation of brake pad material (Garg et al., 2000; Varrica et al., 2013; Wahlin et al., 2006). 31 % of NO2 emissions are contributed by transport sector in the country, followed by power sector and industries. Several studies suggested that pollutants affect the air quality. Parmar et al., 2001 observed that gaseous pollutants as well aerosols contribute to deteriorate the air quality. According to WHO air quality data base, about 99% of global population breathe air that exceeds from recommended air quality limit and causes over 6.5 million deaths every year globally. Around 400-550 thousand premature deaths are because of indoor air Green Growth and Air pollution in India (Dey et al., 2012; Smith, 2000). Air pollution directly affect economic growth of states. Lim et al., (2012) studied effect of ambient air pollution on mortality. Sajith et.al., 2022 studied the association between air pollution attributed disease burden (APADB) with gross state domestic product (GSDP) and the growth in the number of registered motor vehicles in India during 2011 to 2019 and found that APADB inversely correlated with GSDP in most of the state. Major sources of air pollution from residential sector in India are due to use of biomass in cooking and kerosene for lighting. Kumar, M. (2022) has studied that PM10, SO2, NO2 and AQI of some cities of Uttar Pradesh adversely affects the human health and environment. There is increasing number of health issues such as acute respiratory infections (ARI), chronic pulmonary diseases (COPD), asthma, heart diseases, cataract, pneumonia, low birth weight, and tuberculosis all due to indoor air pollution (UNICEF, 2013). Ren et.al., (2021) studied the effect of SO2 pollution on house hold purchases of commercial health insurance. They found that there is a positive association with tendency of residents to participate in commercial health insurance. Vallero (2007) reported that the human health effects of poor air quality are far reaching. Poor air quality mainly affects the respiratory systems and the cardiovascular systems. Individual reaction to air pollutants depends on the types of pollutant a person is exposed to the degree of exposure. Allen et al., (2016) reported that air pollution increases the risk of dementia in people over 50 years. Savio et.al., (2022) reported that maximum, PM10 (57.13-1225.53 µg/m3), total suspended particulates (77.77-1410.27 µg/m3) and CO2 (332.4-655.0 ppm) found during heavy traffic conditions in Srinagar (Kashmir). They also concluded that the pollution load was observed to be maximum during winter season followed by autumn, summer and spring.

Materials and methods: The present investigation is carried out to study the pollutants which adversely affect the air quality of residential as well as commercial /industrial area.The present investigation carried out in five historical, culturally rich and prestigious cities Varanasi, Prayagraj, Mathura, Gorakhpur and Ayodhya in Uttar Pradesh state of India. The Air Quality data of year 2022 (January to December) is collected from official website of Uttar Pradesh pollution control board (UPPCB) and the following parameters are taken for the study.

1. AQI (Air Quality Index)
2. SO_2 concentration (microgram/m^3)
3. NO_2 concentration (microgram/m^3)

4. PM $_{10}$ (particle 10 micrometre) (microgram/m^3)

Annual average values of all four parameters are calculated for analytical and comparative studies.The data has been collected for analytical and comparative study from Saket Nagar (Varanasi), Bharat yantra Nigam (Prayagraj), Regional office Building (Mathura), E M E C (Gorakhpur) and Department of Environment science (Ayodhya) residential areas while for industrial/commercial area data collected from Chandpur (Varanasi), Crossing mahalaxmi takies (Prayagraj), combined effluent plant (Mathura), Geeda (Gorakhpur) and Digambar akhara (Ayodhya) industrial/commercial area for study.The air Quality for these citiesis compared according to WHO`s Global Air Quality Guidelines.Annual normal limit of AQI valueand NO2, SO2 and PM10 normal annual average concentrations according toGlobal Air Quality Guidelines,2021(WHO) of pollutants are given in table.01 and table.02.

S.No.	AQI	Quality
1	0-50	Good
2	51-100	Satisfactory
3	101-200	Moderate Quality (Unhealthy for sensitive groups)
4	201-300	Poor Quality (Unhealthy)
5	301-400	Very Poor Quality (Very Unhealthy)
6	>401	Severe

Table:01

Table: 02

S.No.	Pollutants	Maximum limit (According to AQGs 2021)(microgram/m^3)	
Period of measurement		Annual	24 hours
1	SO_2 concentration (microgram/m^3)	20	40
2	NO_2 concentration (microgram/m^3)	10	25
3	PM $_{10}$ (particle 10 micrometres) (microgram/m^3)	15	45

Observations:

Air Quality Index (AQI):

The data regarding air quality index (AQI) are given in table (3&4) and figure (1,5&6). Persual of data from table (3) shows that the annual average of AQI found 2 to 4 times more than the good AQI (AQGs 2021) in all studied cities/areas. The maximum annual average of AQI (166.40) in all residential area of studied cities was recorded in Saketnagar residential area of Varanasi which is 2.3 time higher than

annual good AQI (0-50).The highest annual average of AQI(313.36) in commercial/industrial area recorded in Geeda (Gorakhpur) while minimum annual average (166.40) recorded in Saketnagar residential area of Varanasi.The Minimum annual Average AQI in recorded 109 in Gorakhpur (EMEC) residential area while 153.64 recorded in Mathura (combined effluent plant) commercial/industrial area in comparison to normal annual average AQI (50). The month wise data shows that maximum AQI found 224 in Saketnagar (Vanarasi) residential area during January 2022 while 372 AQI recorded in Geeda (Gorakhpur) during August 2022. The minimum AQI 69 recorded in residancial area (EMEC,Gorakhpur) as well as in comercial area (crossing Laxmi takies,Prayagraj) during October 2022 and November 2022 respectivly.Perusal of data from table 4 shows that the maximum AQI 372 recorded in Geeda (Gorakhpur) among all the area and cities studied.. The AQI data of all cities shows that air quality of all the studied area/cities was found moderatly poor to very poor.

. **Sulphur dioxide (SO_2) :**

Sulphur dioxide (SO_2) is a toxic gas which evolves during volcanic activities, copper extraction and burning of sulphur bearing fossil fuel. The data regarding SO_2 concentration is presented in table (5 &6) and figure (2,5&6). Perusal of data from table (5 & 6) shows that the highest annual average SO2 concentration recorded in residential area of Varanasi (26.46 microgramme/m3) followed by Prayagraj (26. me/m3) and Mathura (25.51 microgramme/m3) in compression to normal annual value (20 microgramme/m3) while it was found below the normal limit in Gorakhpur and Ayodhya.Perusal of data from table 06 shows that the average annual value of SO_2 concentration in commercial/industrial areas recorded higher in comparison to normal concentration. The highest average annual SO_2 concentration recorded 49.70 microgram/m3 at Geeda industrial area of Gorakhpur.

Among all the cities/area month wise maximum (57.51 microgram/m3) SO_2 concentration was recorded in Geeda industrial area of Gorakhpur during January 2022 while in residential area maximum SO_2 concentration (37.56 microgramme/m3) recorded also during January 2022.The minimumconcentration of SO2 was found 4.73 (microgramme/m3)in EMEC area (residential) ofGorakhpurduringSeptember 2022.The annual average of SO_2 concentration was found below the normal value in EMEC Gorakhpur throughout the year 2022.

Nitrogen dioxide (NO_2) :

Nitrogen dioxide is an intermediate gas produced during synthesis of nitric acid and millions tone of NO_2 produced each year. This gas primarily used in the production of fertilizers. The data from table 07& 8 and figure3,5&6 shows that average annual concentration of NO_2 found almost within normal limit in residential area of all studied cities. Perusal of data from table 07 shows that the highest annual average of NO2 concentration (11.36 microgram/m^3) recorded in residential area of Mathura (regional office building) which is slightly higher than normal value (10 microgram/m^3). Perusal of data from table 08 shows that the highest annual average concentration of NO_2 found 33.44 microgram/m3 in Gida industrial area of Gorakhpur in comparison to normal value (10microgram/m^3). In rest of the cities NO_2 concentration was found below the normal value throughout the year 2022.

PM 10 (Particle 10 micrometres):

Findings on PM10 concentration of studied cities presented in table (9 &10) and figure (4,5&6). The findings of data from residential area (table 09) show that maximum annual average particulate matter

(PM_{10}) concentration was found in Varanasi (198.47 microgram/m^3) followed by Prayagraj (193.89 microgram/m^3) which is about 13% higher thannormal annual value (15 microgram/m^3).The minimum annual average concentration (115.80 microgram/m3) was recorded in Gorakhpur (EMEC) which was found about 8% higher than normal value (15 microgramme/m3). Perusal of data from table 10 clearly indicate that the PM10 concentration of commercial/industrial area is found very alarming and serious. The highest annual average concentration of PM10 particles recorded 355.06 microgram/m3 Geeda (Gorakhpur) which is about 23.7% higher than normal PM10 (15 microgram/m3) concentration Month wise analysis of data shows that the maximum PM10 concentration in residential area recorded 273.89 microgram/m3 in Saket Nagar (Varanasi) during January 2022 while 407.38 microgram/m3 Geeda (Gorakhpur) commercial area during August 2022.

Table :03

Name of city	Type of area	AQI during 2022												
Months		Jan.	Feb.	Mar	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	**Average**
Varanasi	Saket Nagar	224.00	160.00	156.00	165.00	170.00	168.00	164.00	161.00	157.00	139.00	NA	NA	**166.40**
Prayagraj	Bharat yantra Nigam	206.00	181.00	180.00	177.00	163.00	170.00	158.00	123.00	139.00	153.00	141.00	NA	**162.82**
Mathura	Regional office Building	165.00	155.00	154.00	142.00	144.00	134.00	126.00	127.00	135.00	152.00	144.00	NA	**143.45**
Gorakhpur	E M E C	116.00	118.00	111.00	106.00	117.00	120.00	117.00	120.00	69.00	78.00	127.00	NA	**109.00**
Ayodhya	Department of Environment science	165.00	155.00	156.00	159.00	142.00	160.00	161.00	159.00	153.00	157.00	179.00	NA	**158.73**
Normal (Good) value														**50.00**

AIR QUALITY INDEX OF RSIDENTIAL AREA(AQI)

Table:04

Name of city	Area name	AQI during 2022												
Months	Months name	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Average
Varanasi	Chandpur	279.00	251.00	214.00	226.00	242.00	228.00	218.00	205.00	194.00	114.00	136.00	NA	209.73
Prayagraj	Crossing mahalaxmi talkies	306.00	198.00	184.00	182.00	184.00	176.00	166.00	163.00	175.00	185.00	69.00	NA	180.73
Mathura	Combined effluent plant	165.00	171.00	169.00	152.00	151.00	134.00	139.00	153.00	156.00	152.00	148.00	NA	153.64
Gorakhpur	Geeda	355.00	357.00	337.00	333.00	355.00	369.00	280.00	372.00	171.00	226.00	292.00	NA	313.36
Ayodhya	Digambarakhara	165.00	155.00	156.00	157.00	158.00	161.00	160.00	160.00	155.00	163.00	185.00	NA	161.36
Normalvalue														50.00

AIR QUALITY INDEX OF COMMERCIAL/INDUSTRIAL AREA(AQI)

Table :05

Name of city	Type of area	SO_2 Concentration (microgram/m^3) during 2022												
Months		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Average
Varanasi	Saket Nagar	32.32	25.93	25.16	26.88	26.47	26.01	25.63	25.25	24.88	26.07	NA	NA	26.46
Prayagraj	Bharat yantra Nigam	37.56	21.50	26.30	24.80	24.10	24.60	26.30	23.40	23.70	28.80	26.30	NA	26.12
Mathura	Regional office Building	32.00	27.00	28.00	29.00	23.00	23.00	23.00	18.00	25.00	26.00	26.60	NA	25.51
Gorakhpur	E M E C	5.09	5.02	5.63	5.38	5.82	6.06	5.58	5.86	4.73	5.17	5.69	NA	5.46
Ayodhya	Department of Environment science	24.96	17.46	16.83	16.61	5.37	18.67	17.06	15.71	18.40	15.00	26.13	NA	17.47
Normal annual value														20.00

SO_2(microgram/m^3) CONCENTRATION OF RESIDENCIAL AREA

Table:06

Name of city	Area name	SO2 concentration(microgramme/m3) during 2022												
Months		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Varanasi	Chandpur	48.18	33.59	29.37	30.79	30.33	29.06	27.79	26.43	25.31	34.80	45.33	NA	32.82
Prayagraj	Crossing mahalaxmi talkies	42.28	22.50	27.80	25.90	26.90	26.60	29.40	29.60	31.30	36.30	30.60	NA	29.93
Mathura	Combined effluent plant	32.00	30.00	29.00	29.00	28.00	23.00	25.00	25.00	28.00	26.00	30.00	NA	27.73
Gorakhpur	Gida	57.52	55.94	52.31	51.62	52.77	53.60	25.21	54.82	45.02	47.97	49.92	NA	49.70
Ayodhya	Digambar akhada	24.96	17.46	19.09	18.27	14.20	18.70	18.70	16.85	23.30	18.31	29.65	NA	19.95
Normal annual value														20.00

SO_2 (microgram/m^3) CONCENTRATION OF COMMERCIAL/INDUSTRIAL AREA

Table:07

Name of city	Area of study	NO_2 Concentration (microgram/m^3) during 2022												
Months		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Average
Varanasi	Saket Nagar	8.10	6.08	5.90	6.31	6.21	6.10	6.01	5.92	5.83	14.71	NA	NA	**7.12**
Prayagraj	Bharat yantra Nigam	3.89	2.30	2.30	2.20	2.30	2.30	2.20	2.40	2.40	2.90	2.70	NA	**2.54**
Mathura	Regional office Building	15.00	12.00	12.00	12.00	11.00	11.00	10.00	9.00	10.00	11.00	12.00	NA	**11.36**
Gorakhpur	E M E C	1.82	1.77	1.76	1.65	1.76	1.81	1.74	1.78	1.53	1.58	1.66	NA	**1.71**
Ayodhya	Department of Environment science	6.76	7.55	5.40	16.61	5.37	6.48	6.18	5.27	4.84	3.33	3.73	NA	**6.50**
Normal annual value														**10.00**

NO_2 (microgram/m^3) CONCENTRATION OF RESIDENCIAL AREA

Table:08

Name of city	Area name	NO2 concentration(microgramme/m3) during 2022												
Months		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Varanasi	Chandpur	8.16	8.17	7.13	7.48	7.37	7.06	6.74	6.41	6.14	11.19	17.42	NA	8.48
Prayagraj	Crossing mahalaxmi talkies	4.38	2.70	2.70	2.50	2.60	2.40	2.50	2.90	2.90	3.60	3.20	NA	2.94
Mathura	Combined effluent plant	15.00	13.00	14.00	14.00	13.00	11.00	11.00	11.00	12.00	11.00	13.00	NA	12.55
Gorakhpur	Gida	39.09	38.27	36.35	35.33	36.05	36.32	7.98	36.74	33.59	33.45	34.67	NA	33.44
Ayodhya	Digambara khara	6.78	7.55	6.68	6.71	5.37	7.33	5.99	5.99	6.10	4.40	5.32	NA	6.20
Normal annual value														10.00

NO_2 (microgram/m^3) CONCENTRATION OF COMMERCIAL/INDUSTRIAL AREA

Table: 09

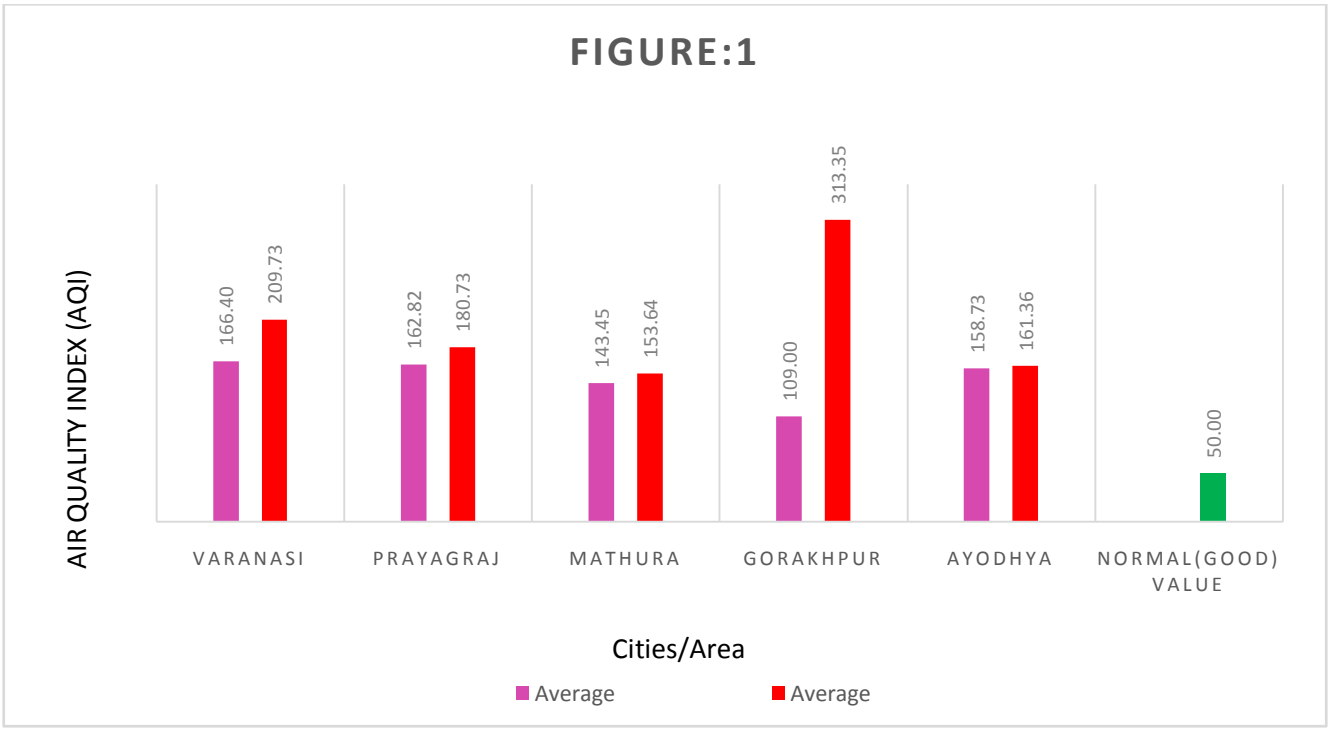
Name of city	Area of study	PM_{10} Concentration(microgram/m^3) during 2022												
		Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Average
Varanasi	Saket Nagar	273.89	190.37	184.66	197.30	205.13	201.53	196.13	190.91	185.88	158.94	NA	NA	198.47
Prayagraj	Bharat yantra Nigam	255.74	221.00	220.00	216.00	195.00	205.00	187.00	134.00	159.00	179.00	161.00	NA	193.89
Mathura	Regional office Building	194.00	183.00	181.00	163.00	166.00	130.05	139.00	140.00	153.00	178.00	166.00	NA	163.00
Gorakhpur	E M E C	123.72	126.34	116.75	108.65	125.66	130.05	124.93	130.23	68.71	77.66	141.06	NA	115.80
Ayodhya	Department of Environment science	210.96	182.81	184.06	188.62	187.30	190.16	191.06	188.00	179.53	185.18	218.24	NA	191.45
Nornal annual value														15.00

PM10(microgram/m^3) CONCENTRATION OF RESIDENCIAL AREA

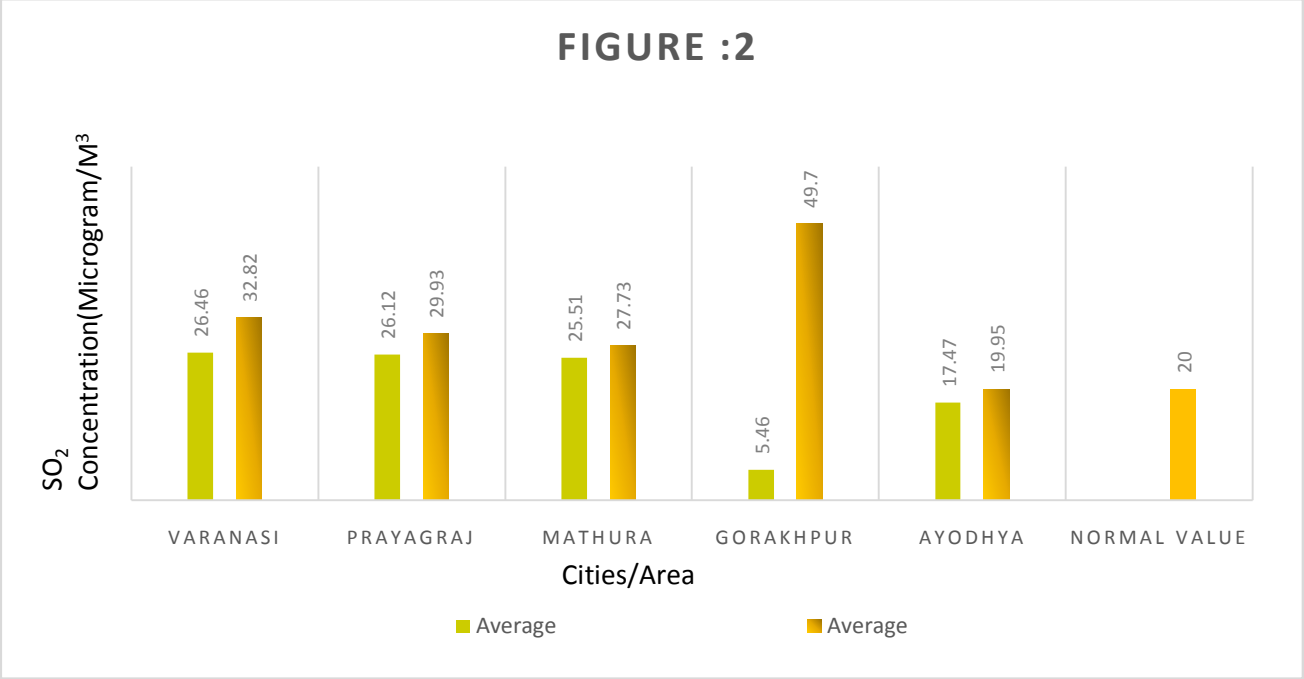
Table:10

Name of city	Area name	PM 10(Micrometer) concentration(microgramme/m^3) during 2022												
Months		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Varanasi	Chandpur	329.35	301.46	263.12	275.68	291.79	277.62	268.05	254.94	240.37	120.96	153.57	NA	252.45
Prayagraj	Crossing mahalaxmi talkies	355.18	247.00	226.00	223.00	226.00	214.00	199.00	194.00	213.00	227.00	204.00	NA	229.83
Mathura	Combined effluent plant	197.00	207.00	204.00	178.00	176.00	150.83	159.00	179.00	184.00	178.00	172.00	NA	180.44
Gorakhpur	Geeda	393.65	395.59	379.88	376.28	393.77	405.11	329.68	407.38	206.11	276.11	342.13	NA	355.06
Ayodhya	Digambar akhara	210.96	182.81	183.43	185.81	187.30	191.44	189.81	189.47	182.33	194.24	227.64	NA	193.20
Normal annual value														15.00

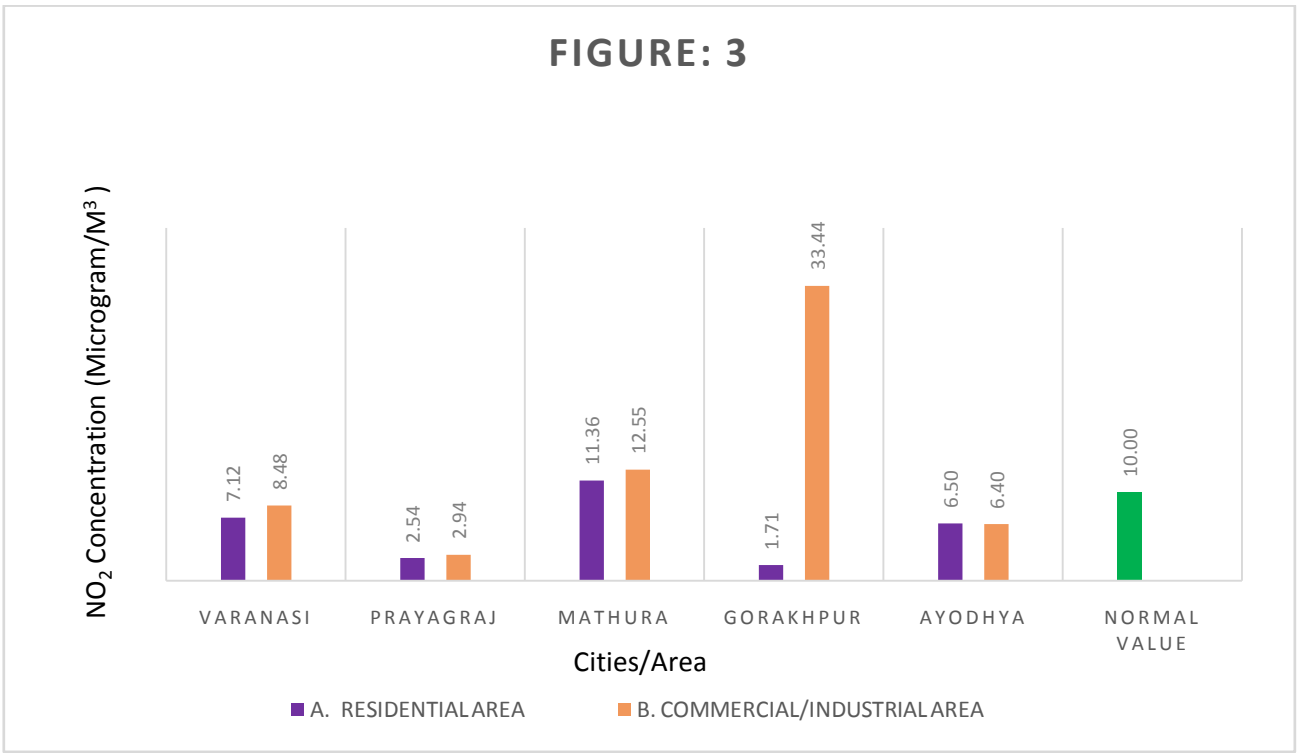
PM10 (microgram/m^3) CONCENTRATION OF COMMERCIAL/INDUSTRIAL AREA



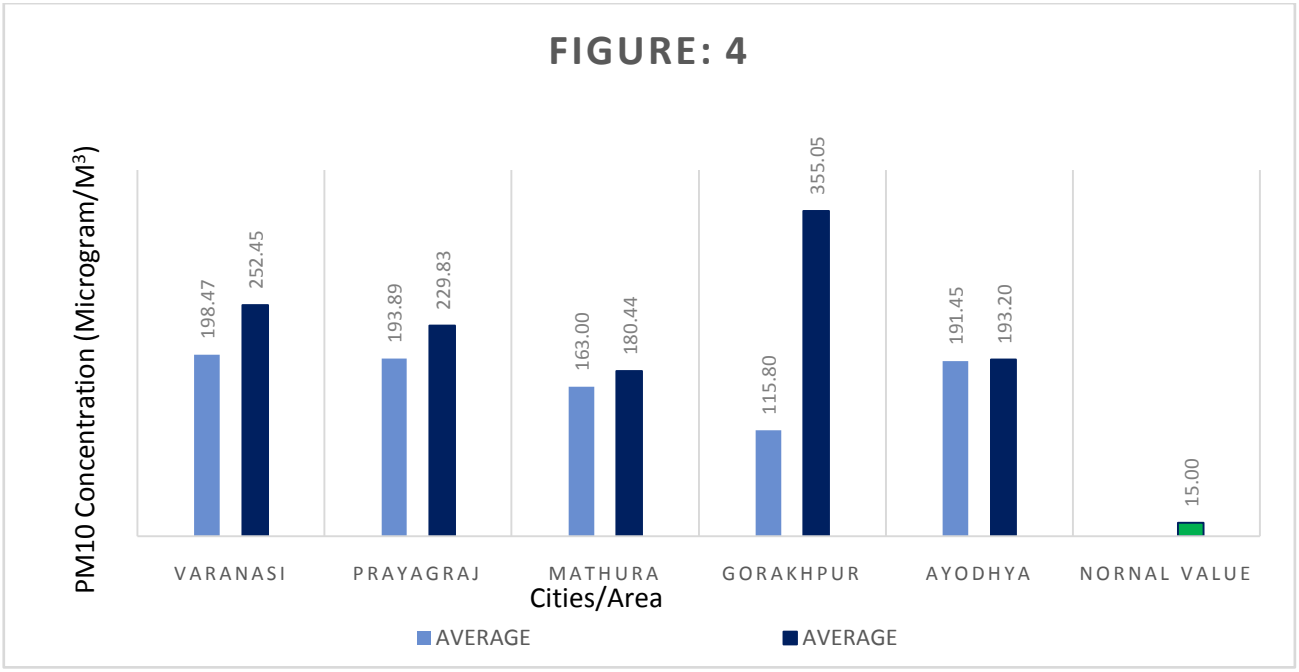
AIR QUALITY INDEX (AQI)



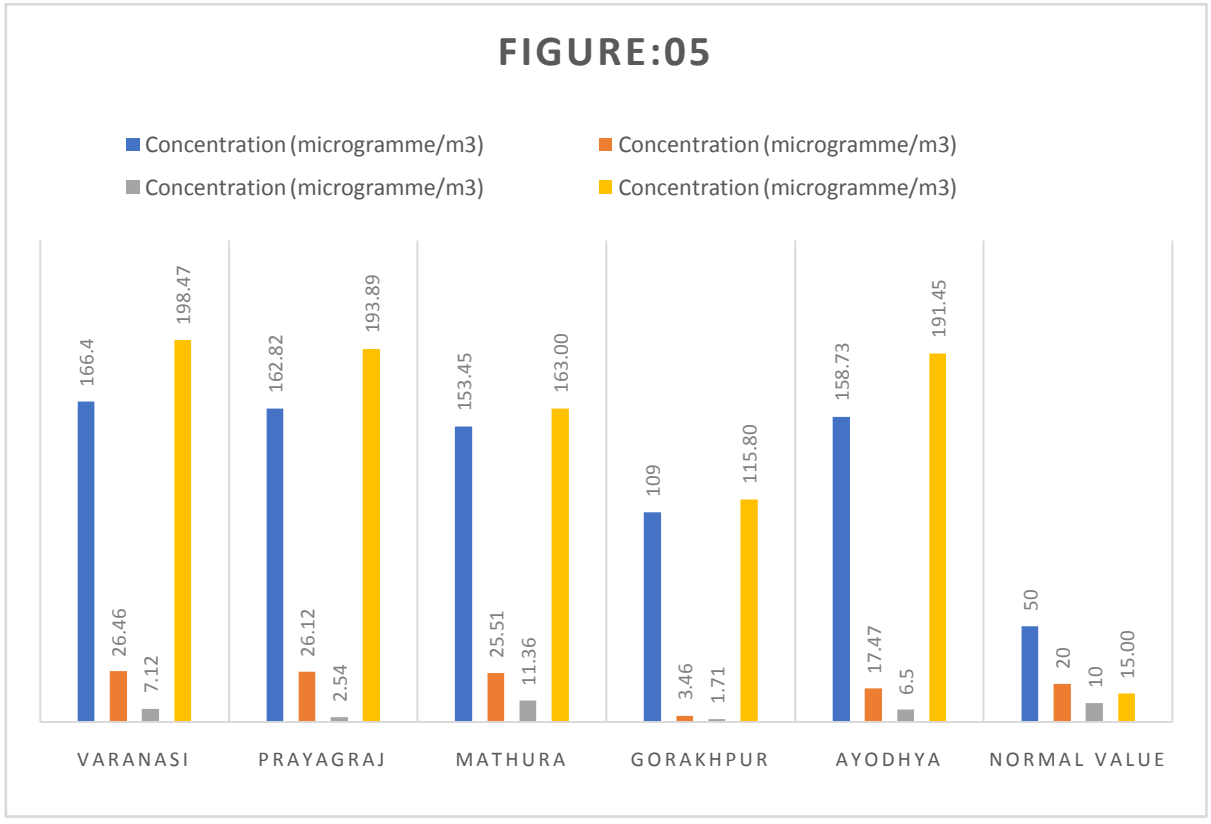
SO_2 Concentration (Microgram /M^3)



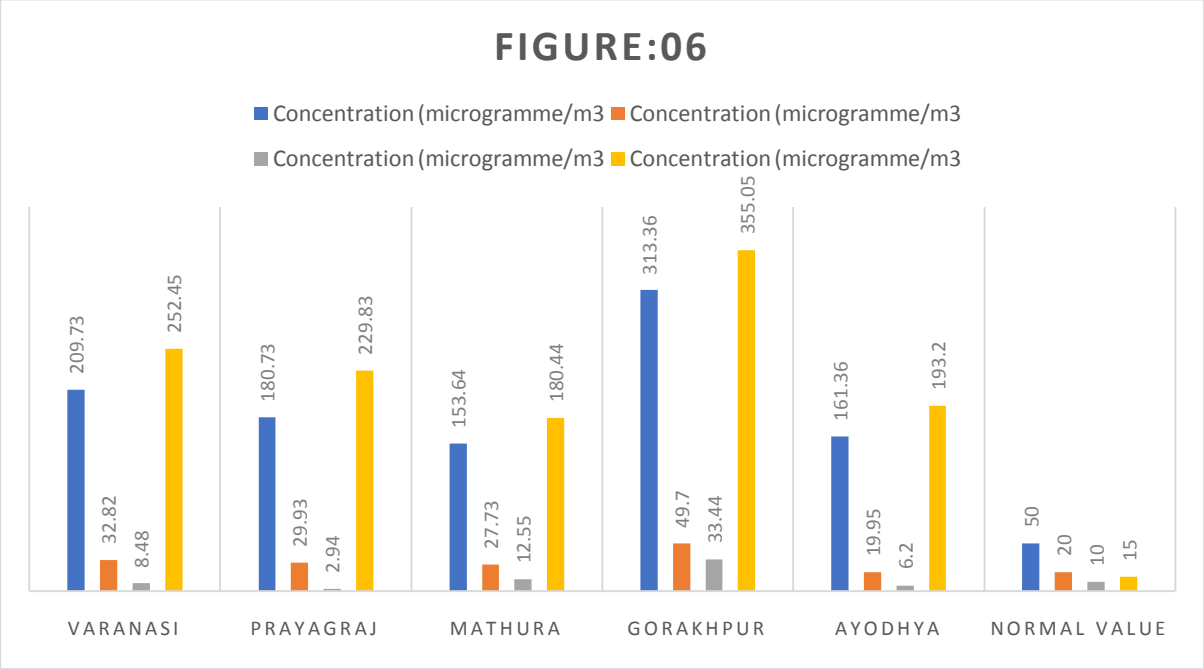
NO_2 Concentration (Microgram/M^3)



PM10 Particulate matter (microgram/m3



Comparative annual average values of AQI, NO2, SO2 and PM10 in residential areas



Comparative annual average values of AQI, NO2, SO2 and PM10 in commercial/industrial areas

CONCLUSION:

Air Quality index of any living area is very important for health, any change in air quality adversely affects human health. According to air quality guidelines (2021) AQI range, 0-50 good for health. AQI above from normal limit causes so many health issues in children as well as adults. Exposure to polluted air can lead to reduce lung function, respiratory problems and asthma. The data of this investigation shows that AQI of all the areas of studied cities found higher than normal range. Annual average value of AQI in residential area of Varanasi, Prayagraj and Ayodhya was found 166.40,162.82 and 158.73 microgram/m3 which is unhealthy for all sensitive age groups people. The commercial/industrial area of these cities found highly polluted. The highest AQI annual average recorded 313.36 microgram/m3 in Geeda (Gorakhpur).

Geeda area of Gorakhpur found highly polluted area among all the cities and its air quality found very poor. Exposure of such air can cause several lung diseases, breathing discomfort and asthma in children as well as adults. AQI of rest of the cities found about 150 which is unhealthy to all age group people.

The perusal of data from this investigation shows that annual average of SO_2 slightly higher in residential areas of Varanasi and Prayagraj while in commercial area it was found above the normal value in almost all the cities. The highest SO2 concentration recorded in Geeda (Gorakhpur) it may be due to more than 20 industries located in this area. The main source of Sulphur dioxide (SO2) in atmosphere of concerned cities is due to burning of fossil fuels (coal and petroleum), smelting of sulphur containing mineral ores, fertilizer, aluminium, steel manufacturing units. Higher concentration of sulphur dioxide irritates the respiratory tract and increases the risk of respiratory tract infections. It may cause coughing, mucus secretion and aggravates asthma and chronic bronchitis. Sulphur dioxide reacts with water and air and produce sulphuric acid.

Nitrogen dioxide (NO_2) is highly reactive gaseous pollutant. Nitrogen dioxide gas are produced in atmosphere due to various natural and human activities. Natural factors like lightening, forest fires and volcanic explosion are main natural sources of NO_2 emissions.Petroleum matter combustion, power

plants, industrial emissions, smoking, kerosine and gas stoves etc. are manmade activities which significantly increase atmospheric NO_2 level. The data from table 07 &08 shows that average annual concentration of NO2 recorded 33.44 microgram/m3 is recorded in Geeda industrial area of Gorakhpur in comparison to normal value 10 microgram/m3. It may be due to more than 20 industries located in this area. High concentration of NO2 may cause several health issues and acid rain. In other studied cities/areas annual average NO2 concentration recorded almost within normal concentration.

Nitrogen dioxide reacts with moisture and ammonia which produce small particles. These small particles can penetrate in respiratory tract and adversely effects on respiratory system. Short term exposure of NO2 causes cardiovascular and respiratory problems and increases death risk. Prolonged exposure in higher concentration of NO2 can develop asthma and increase respiratory infections. The annual average concentration of NO2 above normal limit can be dangerous to human health. Nitrogen oxide reacts with moisture and transforms into nitric acid which precipitate in the form of acid rain on vegetation, soil and may cause the acidification of soils and water bodies in affected areas.

Particulate matter (PM10) is a composition of small droplets of liquid, dry solid fragments, and solid cores with liquid coatings. Its particles are varied in size, shape and chemical composition. They also contain inorganic ions, metallic compounds, elemental carbon, organic compounds, and earth's crust. Dust of construction sites, landfills, agriculture, wildfires, waste burning ash, industrial by products, pollen grains and fragments of bacteria etc also a good source of PM10.

Perusal from table 09 & 10 shows that PM 10 concentration found 8 to 23 time higher in comparison to normal value (15 microgram/m3) studied cities. It may be due to several road construction work and vehicular emissions in residential area of Varanasi & Prayagraj. There are several industries like Gallant, Trident steel Aazam Rubbers, India Glycols etc Industries located in Geeda (Gorakhpur) these industries play a positive role to increase PM 10 concentration in this region. The increased concentration of PM10 can causes many health issues (breathing discomfort, chronic obstructive pulmonary disease (COPD) and asthma), low visibility and soiling of material surface. The International Agency for Research on Cancer (IARC) report (2015) concluded that particulate matter in outdoor air causes lung cancer. Various studies in relation to health indicate that exposure to higher concentration of PM10 increases problem in people suffering from chronic heart or lung disease, children and asthmatic groups.Particulate matter (PM) has been shown in many scientific studies that it adversely affects climate as well as ecosystems. The ambient PM10 mixture with black carbon increase climate temperature (warming) while nitrates and sulphates have cooling effect hence decrease climate temperature. Abrupt change in temperature (warming and cooling) adversely affects various ecosystems.

The adverse effects of the above pollutants can be reduced by implementing some precautionary efforts in all studies cities/areas. The production of BS-II to IV standard vehicle should be immediately stopped and all car or motor bike industries should be starting the production of only BS-VI vehicle. Old vehicles should be gradually phased out with proper scrapping mechanism. A gradual shift from road to rail should be followed in Indian scenario. Electric mobility and use of electric vehicles should be promoted. The production and use of biofuels should be promoted to reduce the emission level. Instalment of APCEs in all industrial units should be made compulsory for all the industries.Air pollution control equipment (APCE) should be enforced for each brick kiln unit and its efficiency should be monitored on regular intervals. ESPs are installed in all the industries to reduce the particulate matter and carbon. Use of LPG for cooking, improved biomass based challahs with higher efficiencies and lower emissions should be promote. Reduction in the number of trips by using own car, avoiding burning leaves, trash,&

other materials and avoid petrol or diesel-powered lawn and garden equipment can reduce the pollutant label of these cities/areas.

Acknowledgement: My humble thanks to Uttar Pradesh Pollution Control Board (UPPCB). I have taken Data of air quality for the year 2022 from official site of UPPCB.

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