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An analytical study on air pollution with special reference to some cities of Uttar Pradesh and its consequences on human health and environment.

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Abstract:

Air is an important factor and basic need of all living beings to respire and live. Natural air has a texture with various components in a proper ratio. The Ratio remains almost in a fix proportion in all the seasons. The deterioration in air quality starts with the urbanization, industrialisation and continuous deforestation. This situation is becoming worst day by day with our progress in different sectors due to exploitation of natural resources. Many hazardous particles, molecules, toxic gases, chemicals and biological factors are playing a key role to deteriorate the air quality which is very serious to all living beings including human as well as environment. Various pollutants i.e. particulate matter (PM 10), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) can change the air texture of any place. Air quality index (AQI) of any residential area is a good indicator of air quality. The annual average concentrations of PM10 and NO_2 in all cities found 10-15 and 2-5 times respectively more than normal standard average value. Month wise data shows that PM10 concentration recorded higher in winter than summer and rainy seasons while season does not significantly affect the NO_2 concentrations in all cities. Sulfur dioxide (SO_2) concentration found less than the standard values in all cities. Air quality index (AQI) in all cities found very higher in comparison to normal value (0-50). The annual average value of AQI in all cities found 101-200 range. This value is moderately serious for health and can causes several health issues in human beings of different age groups. Long time exposure to moderately high AQI (>100) causes breathing discomfort with lungs and heart diseases. The higher concentrations of all these pollutants adversely affect environment and responsible for climatic changes.

Key word: PM-Particulate matter, SO_2 (sulfur dioxide) NO_2 (Nitrogen dioxide), AQI (Air quality index), AQGs (Air quality guidelines), FGD (Flue gas desulfurization), ESP (Electrostatic precipitators), APCE (Air pollution control equipment).

Introduction:

Air pollution is a major problem of all developing countries including India. Any adverse change in atmosphere is very harmful for environmental texture as well as health issues. According to World Air Quality Report (2021), India is ranked to 63 of the 100 most polluted countries. There are so many pollutants suspended in the air which create air pollution and broadly classified in two groups i.e. (i) outdoor (ii) indoor pollutants. The fossil fuel, carbon particles, metallic particles and toxic gases are considered as outdoor pollutants which is due to vehicle, industries and power plants while building materials i.e. asbestos, lead and pollutants i.e. tobacco smokes, kitchen fuel are considered as indoor pollutants. Air pollution in rural areas is mostly due to usages of biomass for cooking (Watson et al.2015). The particulate matter is the major concern in outdoor air pollution. For PM10, 83% of the cities violate national ambient air quality standards (NAAQS).The study also found that PM (particle 2.5 & 10 micrometer) concentrations found 48% of the country's cities which are more than 10 time higher than the WHO guideline (WHO air quality guideline level 2021). The unbalanced utilisation of natural resources, human driven activities i.e. vehicular emissions, industrial waste, burning of fossil fuels, smoke from cooking, the construction sector, crop burning, and power sector etc. are among the biggest sources of air pollution in our country as well as in state Uttar Pradesh. Ambient air pollution has been identified as the fifth biggest cause of mortality (Lim, S.S. et.al. 2012). We are the third largest producer of electricity in the word however our75% electricity production comes from fossil fuel basically coal, oil, and gas. The Coal based thermal power plants are considered as the major contributors to air pollution. It produces CO_2, SO_2 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 effect 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. 31 % of NO2 emissions are contributed by transport sector in the country, followed by power sector and industries. 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. 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 from use of biomass in cooking and kerosene for lighting. 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 (IAP) (UNICEF 2013).

Materials and methods:

The present investigation is carried out to study the pollutants which adversely affect the air quality in 10 highly populated cities of Uttar Pradesh. The Air Quality data for year 2021 is collected from official website of Uttar Pradesh pollution control board (UPPCB) and the following parameters are taken for the study. Annual average values of all parameters are calculated for analytical and comparative studies.

1. PM 10 (particle 10 micrometer) (microgram/m^3)
2. SO_2 concentration (microgram/m^3)
3. NO_2 concentration (microgram/m^3)
4. AQI (Air Quality Index)

The data is collected from residential areas of Lucknow, Kanpur, Agra, Ghaziabad, Varanasi, Allahabad (Prayagraj), Meerut, Moradabad, Mathura and Muzaffarnagar cities of Uttar Pradesh to know the impact of above pollutants on air quality, human health and environment. Air Quality analysis is made in comparison to AQGs.

Global Air Quality Guidelines (WHO) of pollutants and AQI (2021) are as follows

S.N.	Pollutants	Averaging Time	Value according to AQGs (2021) (microgram/m^3)
1	Particulate Matter (PM10)	Annual	15
		24 hours	45
2	Sulfur dioxide (SO_2)	Annual	20
		24 hours	40
3	Nitrogen dioxide (NO_2)	Annual	10
		24 hours	25

S.N	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

Observations:

PM 10 (Particle 10 micrometer) :

Analytical findings on PM 10 concentration in the atmosphere of several cities presented in table (1) and figure (1). The data of PM 10 (microgram/m^3) concentration is collected from residential areas of concerned cities of Uttar Pradesh. The findings of data show that maximum annual average particulate matter (PM10) concentration was found in Prayagraj (219) which is about 20% more than average annual value (183), while minimum concentration (155) was recorded in Muzaffarnagar city. The data from table (1) clearly indicates that annual average value of PM10 is 10 to 15 times higher than air quality guidelines 2021 in comparison to standard

annual value (15 microgram/m^3) in all cities. Month wise analysis of data of PM10 concentration in the atmosphere is also studied in all cities. Minimum annual average concentration was recorded 55 microgram/m^3 (Meerut) in September month while maximum PM10 concentration was found 370 (Prayagraj) in October month in the year 2021.

Sulfur dioxide (SO_2) :

Sulfur 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 (2) and figure (2). Perusal of data from table (2) shows that maximum SO_2 annual average concentration was recorded in Moradabad (17.91) followed by Mathura (16.85) than Meerut (15.05) which is about 81% ,70% and 51% respectively more than annual average concentration (9.91). Minimum SO_2 annual average concentration was recorded in Allahabad (Prayagraj) city. Among all the cities maximum SO_2 concentration was recorded in Moradabad e.i.32 in during January 2021 while minimum concentration was found 0.20 in Prayagraj city in January 2021. The annual average SO_2 concentration was found less in comparison to normal annual average SO_2 concentration (20 microgram/m^3) in all studied cities.

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 of NO_2 concentration are presented in table (3) and figure (3). Perusal of data from table (3) shows that annual average NO_2 concentration was 30 in all concerned cities. The highest annual average of NO_2 concentration (57microgram/m^3) was recorded in Kanpur followed by Meerut (35 microgram/m^3) and Banaras (32 microgram/m^3). There was 90% increase recorded in annual average of NO_2 concentration in Kanpur in comparison to normal annual average value (10 microgram/m^3). Minimum average NO_2 concentration was found 21 in Moradabad district of Uttar Pradesh. NO_2 concentration was found 2 to 5 times more in comparison to standard value (annual value 10 microgram/m^3) in all cities. In overall months maximum NO_2 concentration recorded in Kanpur (87) during February while minimum concentration found 10 (microgram/m^3) in two successive months i. e. August and September 2021 in Ghaziabad city.

Air Quality Index (AQI):

The data regarding air quality index (AQI) are given in table (4) and figure (4). Persual of data from table(4) shows that the maximum annual average of AQI (188) was found in Agra district which is 17% more than annual average of AQI (161) among all concerned cities . Minimum annual Average AQI recorded i.e.142 in Muzaffarngar district which is about 12% less than average AQI among all studied cities of Uttar Pradesh during year 2021. Month wise data shows that maximum AQI found 325 in Muzaffarnagar district in November while minimum AQI 90 recorded in Varanashi during June 2021.The AQI data of all cities shows that air quality of all the concern cities was found moderatly poor .

TABLE 1

S.NO.	CITY	PLACE	CONCENTRATION OF PM 10 (microgram/m^3)												
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1	LUCKNOW	Mahanagar	269	215	216	238	na	122	120	97	92	133	201	186	**172**
2	KANPUR	Kidvainagar	251	223	163	151	115	188	174	167	167	171	197	211	**181**
3	AGRA	Nunhai	274	269	296	299	143	210	108	94	67	202	296	285	**212**
4	GAZIABAD	Lohiyanagar	265	253	256	205	na	168	129	129	102	178	334	252	**206**
5	VARANASI	Jawaharnagar	273	238	202	160	139	90	97	96	108	218	246	295	**180**
6	PRAYAGRAJ	Bharatyantra nigam	231	272	277	207	184	191	215	201	203	207	217	225	**219**
7	MEERUT	Kesar road	281	239	231	228	167	164	150	109	55	92	194	205	**176**
8	MORADABAD	PTC	243	235	223	203	na	91	91	102	131	144	189	209	**169**
9	MATHURA	Regional office building	177	172	171	168	114	166	165	135	128	155	226	179	**163**
10	MUZAFFAR NAGAR	Kamla cinema building	121	122	121	184	na	114	112	113	93	106	370	252	**155**
AVERAGE															**183**

Month wise particulate matter ($PM10_{)}$ concentration (2021)

TABLE 2

S.NO.	CITY	PLACE	CONCENTRATION OF SO_2 (microgram/m^3)												
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVR
1	LUCKNOW	Mahanagar	0.20	7.80	8.66	7.58	na	7.20	6.50	5.70	7.40	7.10	10.00	7.90	**6.91**
2	KANPUR	Kidvainagar	16.89	20.34	8.66	8.50	7.76	8.81	8.26	8.09	8.23	8.44	9.69	10.23	**10.33**
3	AGRA	Nunhai	4.10	4.00	4.20	4.10	3.96	4.30	4.20	4.40	4.00	5.00	5.80	4.60	**4.39**
4	GHAZIABAD	Lohiyanagar	7.16	7.38	7.43	8.75	na	6.20	6.60	6.80	7.00	7.40	5.80	8.40	**7.17**
5	VARANASI	Jawaharnagar	8.09	8.09	6.06	6.11	5.64	5.40	5.08	4.37	4.89	7.12	8.27	8.72	**6.49**
6	PRAYAGRAJ	Bharat yantra nigam	1.30	1.50	1.60	1.80	1.73	2.10	2.30	2.00	1.90	1.80	2.80	3.80	**2.05**
7	MEERUT	Kesar road	8.40	8.60	8.30	7.80	5.60	8.30	7.80	6.20	6.90	91.50	10.00	11.20	**15.05**
8	MORADABAD	PTC	32.00	19.00	17.00	18.00	na	14.00	14.00	13.00	17.00	18.00	19.00	16.00	**17.91**
9	MATHURA	Regional office building	17.00	18.40	19.60	25.06	na	20.00	16.60	16.70	15.50	14.10	11.10	11.30	**16.85**
10	MUZAFFAR NAGAR	Kamla cinema building	12.00	12.00	11.00	11.00	9.00	11.00	22.00	11.00	10.00	11.00	11.00	12.00	**11.92**
AVERAGE															**9.91**

Month wise Sulfur dioxide ($SO_{2)}$ concentration (2021)

TABLE 3

S. NO.	CITY	PLACE	NO_2 CONCENTRATION (microgram/m^3)												
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVE
1	LUCKNOW	Mahanagar	36	34	33	35	na	28	27	28	26	30	31	31	**31**
2	KANPUR	Kidvainagar	69	87	52	49	40	52	51	49	51	52	62	66	**57**
3	AGRA	Nunhai	30	43	35	36	35	22	18	14	12	22	39	37	**28**
4	GHAZIABAD	Lohiyanagar	37	42	40	34	na	16	11	10	10	19	34	33	**26**
5	VARANASI	Jawaharnagar	45	42	29	29	24	24	24	21	26	34	39	49	**32**
6	PRAYAGRAJ	Bharat yantra nigam	22	22	26	24	24	26	27	23	19	14	29	38	**24**
7	MEERUT	Kesar road	41	44	43	39	28	33	28	24	23	32	43	41	**35**
8	MORADABAD	PTC	43	24	21	23	Na	16	16	16	21	22	23	21	**22**
9	MATHURA	Regional office building	28	27	26	26	20	26	25	25	22	28	26	25	**25**
10	MUZAFFAR NAGAR	Kamla cinema building	20	21	23	14	na	24	14	14	21	21	32	31	**21**
AVERAGE															**30**

Month wise Nitrogen dioxide (NO_2) concentration (2021)

TABLE 4

S.NO.	CITY	PLACE	AIR QUALITY INDEX (AQI)												
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
1	LUCKNOW	Mahanagar	226	263	220	198	Na	151	135	111	120	127	188	188	**175**
2	KANPUR	Kidvainagar	201	182	142	134	110	159	149	144	145	147	165	174	**154**
3	AGRA	Nunhai	224	219	246	249	129	167	105	94	168	168	246	235	**188**
4	GHAZIABAD	Lohiyanagar	215	203	206	170	Na	145	119	119	152	152	184	202	**170**
5	BANARAS	Jawaharnagar	223	192	168	141	126	90	97	96	178	178	197	145	**153**
6	PRAYAGRAJ	Bharat yantra nigam	187	222	227	171	156	161	177	167	171	171	178	183	**181**
7	MEERUT	Kesar road	231	192	187	185	145	143	133	106	129	129	163	170	**159**
8	MORADABAD	PTC	195	190	182	169	Na	91	91	101	129	129	159	173	**146**
9	MATHURA	Regional office building	151	148	147	145	109	144	143	123	137	137	184	153	**143**
10	MUZAFFAR NAGAR	Kamla cinema building	114	115	114	156	Na	109	108	109	104	104	325	202	**142**
AVERAGE															**161**

Month wise Air Quality index (AQI) (2021)

FIGURE 1

Month wise particulate matter ($PM10_{)}$ concentration (2021)

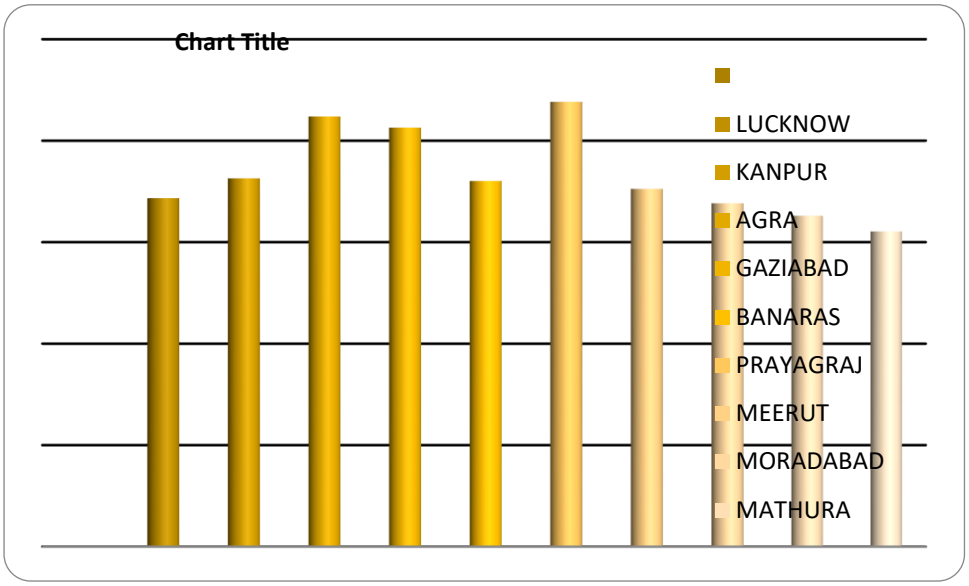


FIGURE 2

Month wise Sulfur dioxide ($SO_{2)}$ concentration (2021)

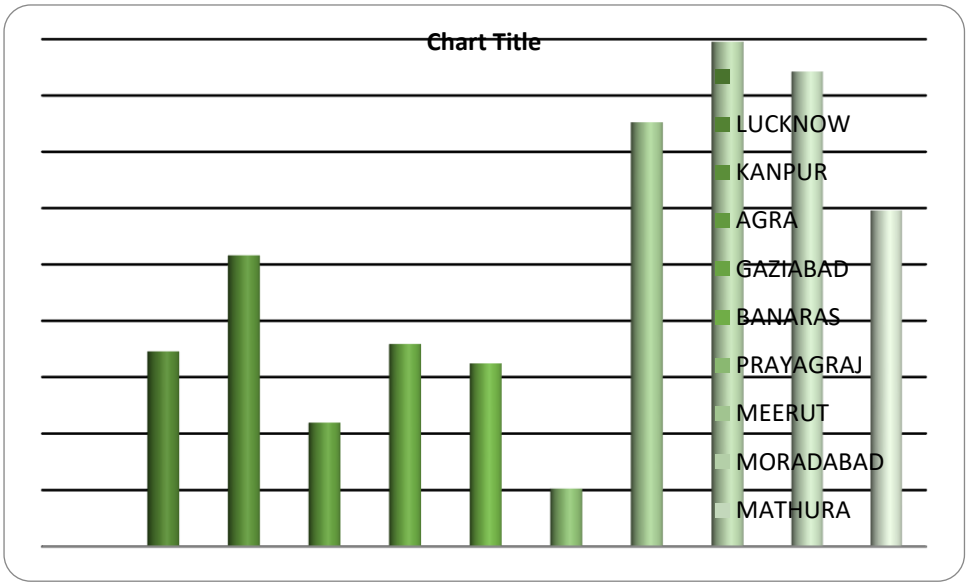


FIGURE 3

Month wise Nitrogen dioxide (NO_2) concentration (2021)

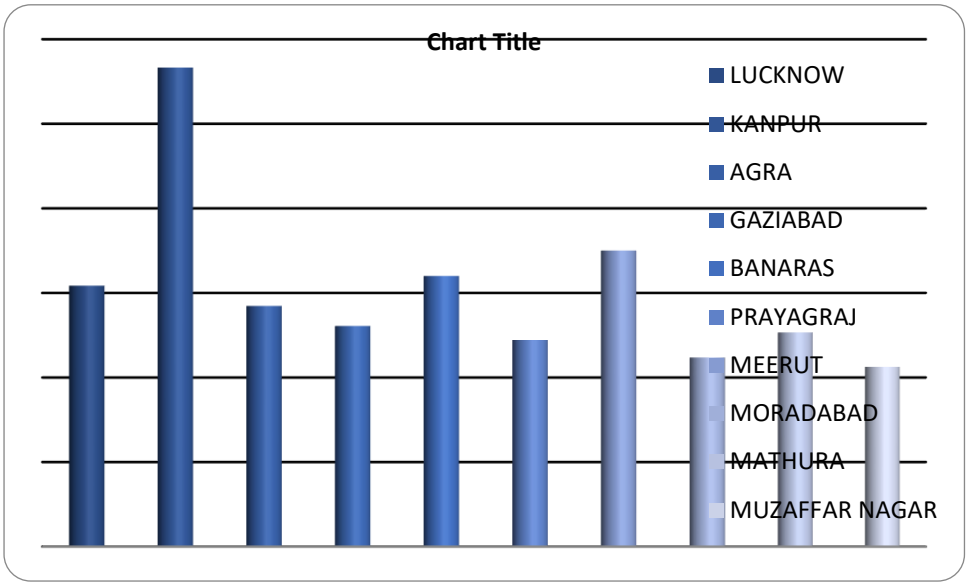
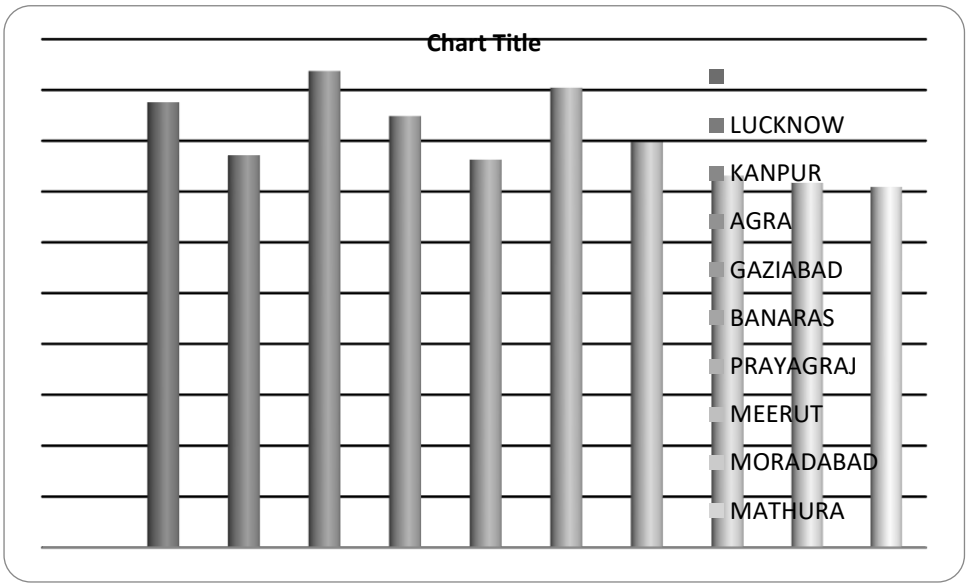


FIGURE 4

Month wise Air Quality index (AQI) (2021)



CONCLUSION:

Airborne particulate matter (PM) is a mixture of many chemicals which includes complex mixture of solids and aerosols. 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 contain inorganic ions, metallic compounds, elemental carbon, organic compounds, and earth's crust. PM10 particles also contain dust of construction sites, landfills and agriculture, wildfires, waste burning ash, industrial byproducts, pollen grains

and fragments of bacteria. Perusal from table (1) shows that highest concentration of PM10 found in Allahabad (Prayagraj) district mainly due to several road construction work and vehicular emissions. There are several industries like Bharat Petroleum corporation limited, Raymond synthetics, Triveni sheet glass and electoplast, Indian oil corporation and more than 10000 unregistered small scale industries situated in Prayagraj. These industries are also play a positive role in increasing PM 10 concentration in Prayagraj. The present investigation shows that the average annual concentration of particulate matter (av.183 microgram/m^3) was found higher than normal limit (10 Microgram/m^3). The increased concentration of PM10 can causes breathing discomfort, low visibility and soiling of material surface.

. The particles of 10 microns or less (PM10) are inhalable into the lungs and can induce adverse health effects. Short-term exposure to PM10 have been associated primarily with worsening of respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD). Higher concentration of PM10 increase chances of hospitalization and emergency hospital visits. Long-term exposure effects of PM10 are less clear, although several studies suggest that long term PM10 exposure increased respiratory mortality rate. 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. Children and infants are very sensitive and susceptible to pm10 because they inhale more air per pound of body weight in comparison to adults, they breathe faster, spend much time in outdoor activities and have smaller body size. Children have immature immune systems it may cause them to be more susceptible to PM than healthy adults.

Particulate matter (PM) has been shown in many scientific studies that it can reduce visibility and also adversely affects climate, ecosystems and different materials. PM 10, affects visibility by altering the way of light. It can absorb and scatter the visible light hence decrease the visibility.PM10 particles may responsible for climate change (Cooling and Warming effects). The ambient PM mixture with black carbon increases climate temperature (warming) while nitrate and sulphate have a cooling effect hence decrease climate temperature. It adversely affects various ecosystems. PM deposition into water bodies affects water quality and clarity. The metal and organic compounds in PM have potential to alter plant growth and yield. PM deposition on various surfaces leads to soiling of materials.

Sulfur dioxide (SO_2) is produced by burning fossil fuels (coal and petroleum) and by the smelting of mineral ores that contain sulphur. It is also produced from some industrial processes e.g. fertilizer manufacturing, aluminium smelting and steel manufacturing. Erupting volcanoes can be a significant natural source of sulphur dioxide emissions. According to who global air quality guidelines (2021) The recommended amount SO_2 in air are as follows:

These standard values are designed to protect sensitive individuals, such as children and asthmatics. Sulphur dioxide affects the respiratory system, particularly lung function, and eyes. Higher concentration of sulphur dioxide irritates the respiratory tract and increases the risk of respiratory tract infections. It causes coughing, mucus secretion and aggravates asthma and chronic bronchitis. Sulphur dioxide reacts with water

and air and produce sulphuric acid, which is the main component of acid rain. Acid rain has following adverse effects.

- cause deforestation
- acidify water bodies
- corrode building materials and paints.
- Increase pH of water and soil

The perusal of data from this investigation shows that annual average of SO_2 found 9.91 microgram/m3 in all the cities which is less than average annual concentration i.e. 20 microgram/m3 hence does not affect health but can cause corrosion of buildings in Moradabad, Mathura and Meerut.

Nitrogen dioxide (NO_2) is highly reactive gaseous outdoor pollutant, having reddish brown colour with pungent odour. Its emissions in atmosphere are due to natural and human activities. Natural factors like lightening, forest fires and volcanic explosion are main natural sources of NO_2 emissions while petroleum matter combustion, smoking, gas stoves and oil stoves are manmade activities which significantly increase atmospheric NO_2 level. The data of this investigation shows that average annual concentration of NO_2 is higher than normal limit (10 microgram/m^3) in all the cities. The highest annual average was found in Kanpur (57 microgram/m^3) followed by Meerut it may be due to fertilizer manufacturing units and vehicle emissions it may causes health issues and acid rain.

Nitrogen dioxide reacts with moisture and ammonia which produce small particles. These small particles can penetrate in respiratory tract and adversely affects on respiratory system. Short term exposure of NO_2 causes cardiovascular and respiratory problems and increases death risk. Prolonged exposure in higher concentration of NO_2 can develop asthma and increase respiratory infections. The annual average concentration of NO_2 above from 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 causes the acidification of soils and water bodies. Acid rain is responsible for depletion of soil, vegetation, discoloration of clothing, fabrics, corrosion of construction metals and deterioration of building material. NO_2 promotes the formation of ozone with the help of solar radiation. Ozone accumulates in lower layer of the atmosphere and directly participates in greenhouse effect. NO_2 is also responsible for formation of aerosols which reduces visibility.

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. Short and long term exposure to ambient air pollution can lead to reduce lung function, respiratory infections and asthma. The data of this investigation shows that AQI of all the cities are more than normal range. AQI of Moradabad, Mathura and Muzaffarnagar (101-150) found unhealthy for all sensitive age groups people. 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 more than 150 which is very unhealthy to all people.

Following recommendations should be implemented in various sectors to reduce the air pollution levels in state.

Transport : Considering the fast growth in the vehicular sector, more stringent steps should be taken. Instead of following chronological order for the norms, BS-II fuels should be considered by enabling the Indian refineries to leap from BS-II to BS-VI. An effective inspection and maintenance system should be enforced by the government in the Uttar Pradesh. 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. Government should conduct programs at community level to aware public about the increasing levels of the pollution due to vehicles and promote public transport systems.

Industries: Cleaner fuels should be introduced to reduce the emission levels. Instalment of APCEs in all industrial units should be made mandatory for all the industries and checking should be made regularly. Number of air quality monitoring stations should be increased. Air pollution control equipment (APCE) should be enforced for each brick kiln unit and its efficiency should be monitored on regular intervals.

Power Sector: ESPs are installed in all the power plants but inspection and maintenance systems should be enforced at regular time intervals. Indian emission standards for SO_2 and NO_2 from thermal power plants in India should be developed. As power sector contributes the most in SO_2 emissions from India, FGD's should be installed in more plants as early as possible. Capacity of vigilance authorities in power sector should be strengthen. Government should provide fiscal incentives for compliance and non-compliance

Residential: Enhanced and faster penetration of cleaner fuels like LPG for cooking. The use of improved biomass based chullahs with higher efficiencies and lower emissions should be promoted.

Extra Steps to Reduce Pollution: Some other measures should be followed to reduce the air pollution i.e. reduction in the number of trips we take in our car, eliminate fireplace and wood stove use, avoid burning leaves, trash, and other materials and avoid petrol or diesel-powered lawn and garden equipment.

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