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Review Article

Investigating the Effect of NO_2 and SO_2 Levels on Covid-19 Susceptibility: A Case Study on Diwali 2020

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ABSTRACT

COVID-19 being a respiratory trouble is adversely influenced by increasing air pollution. People with pre-existing medical conditions, particularly respiratory illness, are prone to the COVID-19 virus. Ambient air pollution weakens the immune system and also facilitates the spread of the virus as it gets adsorbed on the particulate matter. Diwali festivals falling at the onset of winters have proven to deteriorate the air pollution levels owing to longer retention time of the pollutants in winters. This study correlates the SO_2 and NO_2 measurements with daily COVID-19 deaths during the first two waves of the pandemic and assesses the air quality variations monitored during the Diwali period in 2019 and 2020 with respect to the gaseous pollutants viz NO_2 and SO_2 in the cities of Delhi and Lucknow. The AQI values recorded for Diwali 2020 were observed to be higher than the previous years' values in general and no strong correlation was observed to have been established between the COVID mortality cases and focused gaseous pollutants.

Key words: Correlation, COVID-19 mortality, Gaseous pollutants.

1. INTRODUCTION

The major air pollutants in India *viz.* SO_2, NO_2, Suspended Particulate matter (SPM) and Respirable SPM (RSPM) are routinely measured by the Central Pollution Control Board (CPCB). Long-term and short term-exposure to these pollutants have been observed to cause a range of health issues [1,2]. Burning of coal, fossil fuels, oil in power plants, and transportation are the major sources of pollutants in the urban air. Short-term exposure usually occurs due to leaks and burning of household trash or firecrackers. The Indian festival of Diwali, like other celebratory events, is marked by exorbitant burning of firecrackers. The latter has been shown to increase air pollution dramatically. Firecrackers are generally composed of a base used for burning (charcoal, sulfur, potassium nitrate, chlorate, perchlorate, and manganese), along with metal salts that burn with vibrantly colored flames. The burning of firecrackers leads to high emissions of particulates (PM_{10} and $PM_{2.5}$) and gaseous pollutants (SO_2, NO_2, CO).

Numerous studies have linked SO_2 and NO_2 exposure to the dysfunction of the respiratory system. Silo Filler's disease is a bronchopulmonary disorder caused by the inhalation of oxides of nitrogen gas. Studies on short-term NO_2 exposure, as observed in Silo Filler's disease, have shown lung injury and edema [3]. On the cellular level, NO_2 appears to impair the pulmonary defense mechanisms such as phagocytosis [3]. It has been shown to affect Tc lymphocytes and NK- cells that play pivotal roles in antiviral immune defenses [4]. NO_2 has been demonstrated to increase susceptibility to *Klebsiella pneumoniae*, *Streptococcus pneumoniae* and cytomegalovirus infections in mouse models [3]. A case study that examined subjects during/48 h after- indoor NO_2 exposure, reported cough onset, dyspnea, and hemoptysis with no significant effect on lung function [3]. Nitrogen dioxide is an important gaseous pollutant. Being a potent oxidizing agent, it depletes the antioxidant reserve of the respiratory tract lining fluid and consequently results in oxidative stress and inflammation [5]. Sulfur dioxide is a sensory irritant and causes bronchospasm and mucus secretion. SO_2 deposits majorly in the upper respiratory tract and solubilizes into the surface lining fluid as sulfite ions; which brings about bronchoconstriction. The health impacts of SO_2 and NO_2 have been illustrated in Figure 1. Few studies have correlated exposure to SO_2 and the prevalence of asthma [6], atopy [7], and cancer [8] in children. A study found a positive correlation between SO_2 exposure and mortality due to lung cancer in workers [9].

COVID-19 predominantly infects the Respiratory system and can spread via airborne transmission. This suggests a relation between air pollution and the COVID-19 epidemiology. It is known that comorbidities increase the risk of COVID-19 disease contraction and mortality. These include underlying respiratory conditions such as asthma, Chronic obstructive pulmonary disease, Interstitial lung disease, and lung cancer; that are worsened by living in areas with poor air quality. Several studies have correlated air pollutant levels to COVID-19 statistics to find that the worst hit cities were consequently the most polluted ones [10,11]. Some studies have shown an association between ambient NO_2 concentrations and the COVID-19 pandemic [11,12]. The same effect has been highlighted for SO_2 [13]. The role of short-term NO_2 exposure as an independent risk factor is unclear. However, it may be harmful as a co-pollutant. Table 1 summarizes the short term and long-term effects of NO_2 and SO_2 along with their threshold limits. Frontera *et al.* propose

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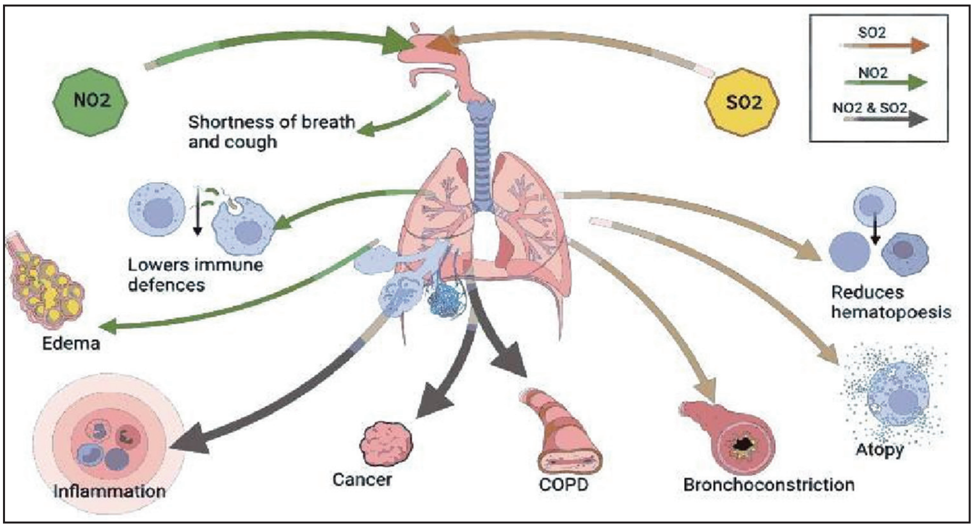

Figure 1: Illustrates the health impacts of NO_2 and SO_2.

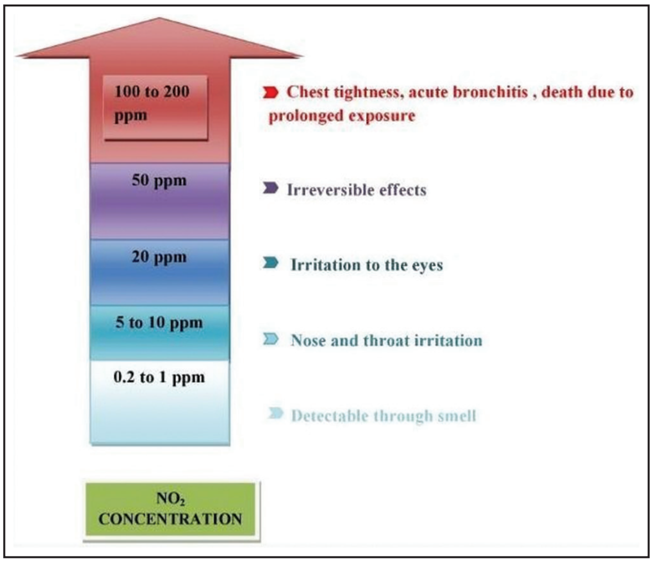

Figure 2: Consequences of increased NO_2 levels.

that NO_2 delivers a "second-hit" post $PM_{2.5}$ exposure and thus worsens the COVID-19 disease progression [3]. Li *et al*. observed the positive effect of NO_2 and $PM_{2.5}$ on COVID-19 incidence [14].

2. MATERIALS AND METHODS

A pilot study was conducted to assess the air quality variation with respect to the gaseous pollutants *viz* SO_2 and NO_2 during Diwali due to the firecracker burning and to investigate a correlation between the daily measurements of SO_2 and NO_2 and COVID-19 deaths, if any, during the first two waves of the pandemic. The study was conducted for the city of Lucknow, the capital of Uttar Pradesh, and Delhi, India's capital territory. The AQI in these two cities had been categorized as "very poor" in 2020 by the CPCB [15]. Since, the present study was focused on assessing the air quality variation around the Diwali period, the variation in AQI with respect to NO_2 and SO_2 were recorded from October 17, 2019 to November 3, 2019 and November 4, 2020–November 21, 2020, with Diwali falling on the 27th of October and 14th of November in the respective years. The average AQI values were recorded from www.aqicn.org and any missing data were excluded from the analysis. The most polluted site was selected as the monitoring stations for the chosen cities. To investigate an association between the COVID-19 deaths and daily measurements of the focussed gaseous pollutants in the atmosphere during the first two waves of the pandemic, COVID-19 related mortality cases were recorded for the month of September 2020 (first wave) and April- May 2021(second wave) from covid19. org. Focussed Gaseous Pollutants' AQI values were also recorded for the same period.

Table 1: Short term and long-term effects of NO_2 and SO_2 ($\mu g/m^3$) and their 24 h average threshold limits.

Pollutant	WHO	CPCB	Short-term effects	Long-term effects
NO_2	25	80	Irritation in the eyes, nose and throat. Headaches, dizziness, fatigue	Respiratory diseases, cardiovascular disorders and cancer
SO_2	40	80	Sneezing and coughing. Burning in the nose, throat, and lungs	Changes in lung function. Decreased fertility. Bronchitis and shortness of breath
			Aggravation of diseases such as asthma and emphysema	

3. RESULTS AND DISCUSSION

During winters, pollutants are suspended in air for a longer period of time due to low wind speed, temperature, inversion height, and high moisture content [15]. The air pollution worsens during the Diwali period falling at the onset of winters in North India due to particulate matter and gaseous pollutant emissions from fireworks. The average AQI values recorded during the Diwali period show the highest value for AQI(42) with respect to NO_2 on the day of Diwali i.e., October 27, 2019, and remain high for the next 5 days that follow. The consequences of prolonged exposure to NO_2 is represented in Figure 2. The SO_2 levels are mostly invariant for both the years around the Diwali period except for a sudden peak on October 8, 2020, followed by a dip and is thus most likely to be an inaccurate measurement, probably a device error. For Delhi, NO_2 levels were observed to be low around the Diwali period suggestive of the ban imposed by the Delhi Government citing pollution concerns but the SO_2 levels seemed to rise after the Diwali day in 2019. Figure 3 illustrates the comparison between the AQI measurements during the Diwali period

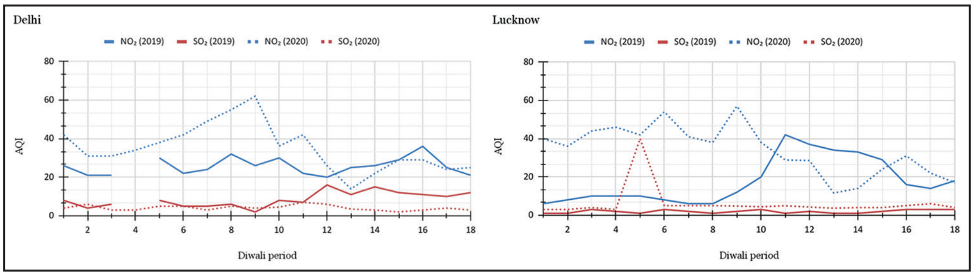

Figure 3: Comparison between AQI with respect to NO_2 and SO_2 during Diwali 2019 and Diwali 2020.

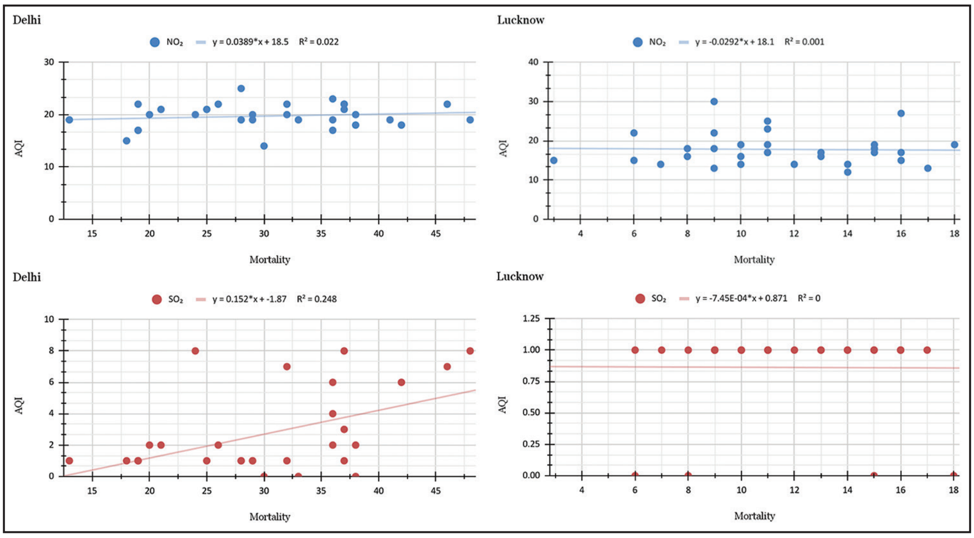

Figure 4: NO_2 and SO_2 versus mortality rate (first wave).

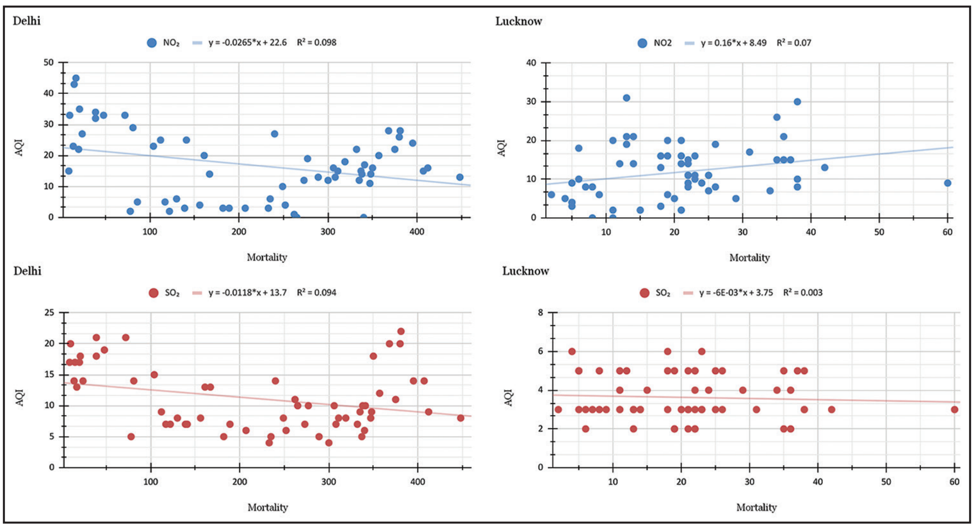

Figure 5: NO_2 and SO_2 versus mortality rate (second wave).

for both the cities. In general, an increase in overall AQI with respect to the gaseous pollutants was observed around the Diwali period in 2020 in comparison to the previous years' AQI values in both Delhi and Lucknow. The air quality had improved throughout the country due to the imposed lockdown but measurements of the pollutants around the Diwali period suggest a different side of the story. The increased AQI could also be a consequence of the increased emissions from industries, power plants, and motor vehicles but an increase on the day of Diwali itself as in the case of Lucknow in 2019 is indicative of the emission of gaseous and particulate pollutants due to firecracker burning. The data for both the cities have been summarized in Table 2.

4. EFFECT OF SO_2 AND NO_2 LEVELS ON COVID-19

For the first wave of the pandemic, a positive correlation was observed only with the SO_2 levels in Delhi, whereas almost no correlation was observed between the gaseous pollutants and COVID mortality cases in Lucknow and with NO_2 levels in Delhi. Pollution levels were low during the first wave because of the induced lockdown, hence, the pollutants did not have much effect on the disease progression. The positive correlation established with SO_2 is arguable since the R^2 value is low. For the second wave of the pandemic, a positive correlation was observed to have been established with the NO_2 levels in Lucknow and negative correlation of the gaseous pollutants with the mortality

Table 2: Average AQI values with respect to SO_2 and NO in Lucknow and Delhi

a) Lucknow						b) Delhi					
Date	NO_2 (AQI)	SO_2 (AQI)	Date	NO_2 (AQI)	SO_2 (AQI)	Date	NO_2 (AQI)	SO_2 (AQI)	Date	NO_2 (AQI)	SO_2 (AQI)
17/10/2019	6	1	04/11/2020	40	3	17/10/2019	26	8	04/11/2020	42	4
18/10/2019	8	1	05/11/2020	36	3	18/10/2019	21	4	05/11/2020	31	6
19/10/2019	10	3	06/11/2020	44	4	19/10/2019	21	6	06/11/2020	31	3
20/10/2019	10	2	07/11/2020	46	3	20/10/2019	NA	NA	07/11/2020	34	3
21/10/2019	10	1	08/11/2020	42	40	21/10/2019	30	8	08/11/2020	38	5
22/10/2019	8	3	09/11/2020	54	5	22/10/2019	22	5	09/11/2020	42	5
23/10/2019	6	2	10/11/2020	41	5	23/10/2019	24	5	10/11/2020	49	3
24/10/2019	6	1	11/11/2020	38	5	24/10/2019	32	6	11/11/2020	55	5
25/10/2019	12	2	12/11/2020	57	4.8	25/10/2019	26	2	12/11/2020	62	4
26/10/2019	20	3	13/11/2020	38	4.4	26/10/2019	30	8	13/11/2020	36.15	4.5
27/10/2019	42	1	14/11/2020	28.85	4.95	27/10/2019	22	7	14/11/2020	42	7
28/10/2019	37	2	15/11/2020	28.57	4.26	28/10/2019	20	16	15/11/2020	26	6
29/10/2019	34	1	16/11/2020	11.61	3.69	29/10/2019	25	11	16/11/2020	14	3.5
30/10/2019	33	1	17/11/2020	14	4	30/10/2019	26	15	17/11/2020	22	3
31/10/2019	29	2	18/11/2020	24	4	31/10/2019	29	12	18/11/2020	29	2
01/11/2019	16	3	19/11/2020	31	5	01/11/2019	36	11	19/11/2020	29	3
02/11/2019	14	3	20/11/2020	22	6	02/11/2019	25	10	20/11/2020	24	4
03/11/2019	18	3	21/11/2020	17	4	03/11/2019	21	12	21/11/2020	25	5

Table 3: Average AQI and mortality rate in Lucknow and Delhi during the first and the second wave of the pandemic

a) First wave (2020)							b) Second wave (2021)					
Date	Lucknow			Delhi			Date	Lucknow			Delhi		
	NO_2	SO_2	Mortality	NO_2	SO_2	Mortality		NO_2	SO_2	Mortality	NO_2	SO_2	Mortality
01-Sep	14	1	7	15	1	18	01-Apr	6	3	2	15	13	9
02-Sep	17	1	11	17	1	19	02-Apr	6	3	9	23	17	14
03-Sep	16	1	13	22	1	19	03-Apr	10	3	6	33	14	10
04-Sep	19	1	10	19	1	13	04-Apr	8	2	8	35	20	21
05-Sep	19	1	18	21	1	25	05-Apr	9	3	5	43	18	15
06-Sep	13	0	17	19	1	29	06-Apr	8	3	7	45	17	17
07-Sep	18	1	15	20	1	32	07-Apr	18	3	6	22	13	20
08-Sep	22	1	9	17	1	19	08-Apr	20	3	11	27	17	24
09-Sep	18	1	8	20	1	20	09-Apr	31	3	13	32	14	39
10-Sep	19	0	11	19	2	28	10-Apr	16	3	23	34	18	39
11-Sep	17	1	16	21	1	21	11-Apr	17	3	31	33	21	48
12-Sep	14	1	10	25	2	28	12-Apr	16	3	21	33	19	72
13-Sep	16	1	10	20	1	29	13-Apr	16	2	18	29	21	81
14-Sep	16	1	8	22	1	26	14-Apr	19	3	13	23	14	104
15-Sep	19	1	15	23	2	36	15-Apr	19	3	26	25	15	112
16-Sep	17	1	15	19	2	33	16-Apr	26	3	35	25	9	141
17-Sep	22	0	6	18	0	38	17-Apr	15	2	36	14	7	167
18-Sep	15	1	16	14	2	30	18-Apr	11	2	22	20	13	161
19-Sep	13	1	9	20	0	38	19-Apr	15	2	22	27	13	240
20-Sep	15	1	6	21	0	37	20-Apr	20	2	19	19	14	277
21-Sep	17	0	13	22	1	32	21-Apr	14	2	21	10	10	249

(Contd...)

Table 3: *(Continued)*

Date	a) First wave (2020)						Date	b) Second wave (2021)					
	Lucknow			Delhi				Lucknow			Delhi		
	NO_2	SO_2	Mortality	NO_2	SO_2	Mortality		NO_2	SO_2	Mortality	NO_2	SO_2	Mortality
22-Sep	12	1	14	22	7	37	22-Apr	16	3	19	16	8	306
23-Sep	14	1	12	17	3	36	23-Apr	21	2	14	14	10	348
24-Sep	14	1	14	19	4	36	24-Apr	13	3	42	20	9	357
25-Sep	18	1	9	20	6	24	25-Apr	14	3	14	16	12	350
26-Sep	25	1	11	22	8	46	26-Apr	20	3	21	26	18	380
27-Sep	23	1	11	18	7	42	27-Apr	30	3	38	28	20	381
28-Sep	30	1	9	22	6	37	28-Apr	21	3	13	28	22	368
29-Sep	27	1	16	19	8	48	29-Apr	21	2	36	24	20	395
30-Sep	15	1	3	19	8	41	30-Apr	15	4	37	22	14	375

Date	b) SECOND WAVE (2021)					
	Lucknow			Delhi		
	NO_2	SO_2	Mortality	NO_2	SO_2	Mortality
01-May	15	5	35	16	11	412
02-May	9	5	24	15	9	407
03-May	11	4	25	13	14	448
04-May	9	3	22	14	8	338
05-May	8	5	38	15	10	311
06-May	9	5	60	12	8	335
07-May	7	3	25	17	9	341
08-May	10	5	38	22	10	332
09-May	8	3	22	12	7	273
10-May	8	3	26	18	7	319
11-May	10	5	23	11	8	347
12-May	11	6	23	12	8	300
13-May	7	3	34	13	4	308
14-May	11	4	22	13	7	289
15-May	14	5	12	15	5	337
16-May	13	5	18	1	5	262
17-May	14	6	22	0	11	340
18-May	6	4	19	0	6	265
19-May	5	5	29	6	10	235
20-May	2	4	21	3	5	233
21-May	5	5	4	4	4	252
22-May	5	6	20	3	6	182
23-May	3	3	18	3	5	189
24-May	4	5	5	3	7	207
25-May	4	5	5	4	6	156
26-May	2	5	11	6	8	130
27-May	2	4	15	5	8	117
28-May	0	4	8	3	7	139
29-May	0	5	11	2	7	122
30-May	1	5	0	2	7	78
31-May	3	6	5	5	5	86

rate in Delhi and SO_2 in Lucknow. Lockdown 2.0 was not successful in keeping the air pollution levels in check due to several industrial and transportation activities operating partially, hence, a positive correlation between NO_2 levels and mortality rate is justifiable. The increased mortality rate during the second wave is presumed to be due to the new viral strain, shortage of oxygen cylinders, and ICU beds. Although COVID-19 is a respiratory problem, in the present study, an overall strong correlation could not be established between COVID-19 mortality cases and the focussed gaseous pollutants during the first two waves of the pandemic. The data are represented in Figures 4 and 5 and (Table 3a and b) give the data for gaseous pollutants under study and COVID-19 deceased cases during the first and second wave of the pandemic.

5. CONCLUSION

The study conducted suggests an increased emission of gaseous pollutants *viz* SO_2 and NO_2 on the day of Diwali and no significant improvement in air quality even after the ban called on the burning of firecrackers by the government in 2017. No direct correlation could be established between the focused gaseous pollutants and COVID-19 deceased cases, hence, the effect of other variables is presumed to be contributing to mortality. Future studies could incorporate controls for such factors. However, the health impacts on exposure to these pollutants and the comorbidities developed as a result cannot be underestimated. Insights in assessing the AQI variation pose to be of immense importance in the context of COVID-19. Present findings having explored the major health impacts of the gaseous pollutants suggest collection of air pollution baseline data that could be useful in the future for the formulation of stringent policies to keep the air pollution levels in check and to lower the transmission probability of the COVID-19 pandemic due to the ambient air pollution in the present.

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