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AIR QUALITY PARAMETERS IN THE INDO-GANGETIC PLAIN DURING COVID-19 INDUCED LOCKDOWN

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ABSTRACT

Indo-Gangetic plain has a population of ~500 million with the majority belonging to low per capita income. The people are mostly working in the unorganized farm and industrial sectors making them vulnerable to respiratory and cardiovascular problems. COVID-19 pandemic induced lockdown brought many activities to a halt including industrial and developmental activities. The present work studies the effect on permitted segmented activities in four phase-wise manners on air quality in terms of suspended particulate matter. It was found that Phase-1 of the lockdown resulted in a reduction of particulate matter especially $PM_{2.5}$. Only a fractional reduction was observed with PM_{10} in comparison to $PM_{2.5}$. This may be because transport and industrial activities were completely halted while agricultural harvest allied activities were permitted. A combined intervention by government bodies to transport, industrial, and agricultural sectors are required in arresting the anthropogenic suspended particulate matters.

KEY WORDS : Air quality, Suspended particulate matters, COVID-19, Indo-Gangetic plain

INTRODUCTION

Indo-Gangetic (IG) plain encompasses northern regions of the Indian subcontinent, including most of northern and eastern India, the eastern parts of Pakistan, Bangladesh, and southern plains of Nepal. IG plain in India comprises the most densely populous region in the world with the majority lying in northern Indian states of Bihar, West Bengal, Uttar Pradesh, Delhi, Punjab, and Haryana and population approximating to 500 million (Census, 2011). The region is infamous for its recurrent smog episodes every year posing a serious threat to the health of children and the elderly. The indicator air quality maps show crimson red warning making environmental and health performance worse during the start of every winter (early November) (Narain *et al.*, 2020). Several factors complement this issue are high population density raising the bars of local pollution from various sources, atmospheric inversion layer in winter, slower wind speed, non-compliance of industrial emission norms and episodic pollution of large-scale stubble burning and firecrackers during the festive season. The particulate matter emission in the IG plain is a natural phenomenon through wind-blown dust in the region. The addition of particular matter by anthropogenic sources alleviates it to toxic levels. The soils of IG plain have micaceous to smectitic properties formed as a result of alluvium acquired from Himalayan and Cratonic rocks (Srivastava *et al.*, 2015). They are mainly formed from the alluvium deposits brought by Himalayan rivers (Pal *et al.*, 2009). Alluvial soils deposited around drainage systems and valley floors are erosion prone to the wind which causes dust emissions (Schepanski *et al.*, 2013). The alluvial soils of IG plain have fine particles which are eroded by wind and cause dust emissions (Desouza *et al.*, 2015) hence contributing to particulate matter in the air. The anthropogenic factors aggravate the particular matter in the IG plain. Despite several policies to address the issue, the situation is not under control and needs to be addressed by scientific and local authorities. Policy and programs in India have focused on tackling this issue at the city-level. However, air pollution does not respect the protocols of the city/state boundaries and thus, can spread in and out of city/state-bounds. Furthermore, in one study it was estimated that approximately 30% of $PM_{2.5}$ concentration in a city is found to be sourced from outside of the city (Ganguly *et al.,* 2020). Similarly, other air pollutants could be sourced outside of the city. Thus, a holistic administrative policy approach is required if the above issue requires effective containment.

The continuous development activities in the IG plain and increasing pollution makes the situation alarming. The recent development of a worldwide pandemic of SARS-CoV-2 or commonly known as COVID-19 spread across India and lead to lockdowns in the country. These lockdowns were implemented in 4 phases beginning from with different level of severity, Phase 1: 25 March – 14 April 2020 (21 days), Phase 2: 15 April – 3 May 2020 (19 days), Phase 3: 4 May – 17 May 2020 (14 days), and Phase 4: 18 May – 31 May 2020 (14 days). During this period the industrial and vehicular emissions were minimal due to the strict lockdown measures enforced. The Ministry of Home Affairs, Government of India laid out detailed guidelines of activities permitted during these phases (detailed guidelines can be found elsewhere (Ministry of Home Affairs, 2020a, 2020b, 2020c, 2020d)). Vehicular and industrial activities were permitted gradually as the phases progressed especially after Phase-1. A segmented approach was adopted in terms of severity of activities permitted from Phase-1 to Phase-4.

Sharma *et al.*, (2020) recently analysed the air quality parameters for few cities across India and found to have significant improvement in air quality during the Phase-1 of the lockdown in India. They found that there was an approximate reduction by 43%, 31%, 10%, and 18% in $PM_{2.5}$, PM_{10}, CO, and NO_2 respectively in India compared to the previous years (2017-19) in the same period. Similarly, Mahato *et al.,* (2020) analysed the air quality and aerosol level for the National Capital of Territory, Delhi, and found during Phase-1 of the lockdown the air quality and aerosol level had improved across Delhi. Kumari and Toshniwal (2020) studied air quality of Delhi and Mumbai during Covid-19 lockdown period and found that $PM_{2.5}$ and PM_{10} had reduced by 55% and 49% respectively. Outside of India, similar effects were observed in major cities that were affected by COVID-19 induced lockdown. A global assessment of the impact of COVID-19 was done on induced lockdown on environmental parameters in the USA, Italy, Spain, and China Zambrano-Monserrate *et al.,* (2020). Zambrano-Monserrate *et al.,* (2020) found improvement in air quality, cleaner beaches, and reduction in noise pollution. However, they also observed a reduction in recycling activities and waste collection as a negative impact of lockdown measures. Bao and Zhang, (2020) estimated the effect of COVID-19 lockdown on air quality parameters in 44 cities in China. They found a strong correlation between reductions in air pollution with travel restrictions imposed during this pandemic. The air quality index (AQI) was found to decrease by 7.80%, and five air pollutants (i.e., SO_2, $PM_{2.5}$, PM_{10}, NO_2, and CO) decreased by 6.76%, 5.93%, 13.66%, 24.67%, and 4.58%, respectively.

Quantifying the status of pollution (i.e. air, water, solid waste, and noise) during the lockdown period has been an important activity assigned to the Government institutions to understand the effect of a pandemic on the environment on short term and long term basis. Further, it is important to know the air quality is strongly correlated with travel restriction as evident from a study in China Bao and Zhang, (2020) and then take corrective measures for improving air quality. $PM_{2.5}$ is reported to cause ischemic heart disease (IHD), cerebrovascular disease (CEV, stroke), chronic obstructive pulmonary disease (COPD), and lung cancer (LC) for the adult population, and acute lower respiratory illness (ALRI) for infants and it has caused 1.1 million annual premature deaths in India and approximately 46% of premature mortality is caused in the IG plains in 2015 (David *et al.*, 2019), (Cohen *et al.*, 2017). Long term exposure to PM_{10} causes mortality due to a rise in respiratory and cardiovascular diseases (Myong, 2016). PM_{10} exposure also resulted in mortality by aggravating respiratory and circulatory problems as observed in Spain causing an estimated 2683 annual deaths (Ortiz *et al.*, 2017).

It is evident that despite the regulations, air pollution menace could not be curbed effectively with continuous developmental activities. Thus, the policies and guidelines for combating air pollution could be effective when addressed holistically. The present work aims to analyse the air quality focused on particulate matters only in the whole IG plain during all 4 phases of lockdown so that it provides insights in developing holistic methods and guidelines to support NCAP effectively.

India has large number of acts and rules and several ambition planes for air quality improvement.

METHODOLOGY

To study the changes in air quality during the lockdown period, the data from 24 cities covering the different regions of IG plain were selected and shown in Fig. 1. The sites are selected based on available data provided by Central Pollution Control Board (CPCB), India, socio-economic differences, and representative coverage of IG plain which are significantly affected by air pollution (detailed in Table 1). The air pollution data is compiled by CPCB in conjunction with respective State Pollution Control Boards (SPCBs) and is made open-accessed on its website (https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing) which is used in the present analysis.

RESULTS AND DISCUSSION

The data were analysed from February 1st, 2020 to June 15th, 2020 to cover the entire period of lockdown till the rainy season started in the IG plain. Fig. 2 shows the variation in $PM_{2.5}$ at all 24 sites in the IG plain. It can be observed that the $PM_{2.5}$ dropped at various cities from 25th March when the first day of Phase-1 lockdown was enforced. The industrial and transport sector which are major emitters of $PM_{2.5}$ was brought to a standstill yielding a sharp decline in the level of $PM_{2.5}$. Cities in Fig. 2(a) found to have 50-60%, 24-55%, 8-25%, and -14-10% reduction of $PM_{2.5}$ respectively from Phase-1 to Phase-4 of lockdown as compared to pre-lockdown phase i.e. February- March 2020. The negative sign observed for some cities (S3 and S4) in the Phase-4 of lockdown indicates the increment in $PM_{2.5}$ level as compared to their pre-lockdown leveldue to increased transport mobility and industrial activities. The $PM_{2.5}$ level continued to increase after Phase-1 of lockdown and thus, the reduction in the $PM_{2.5}$ level continued to decrease as more activities were permitted which increases the emissions in each successive phase.

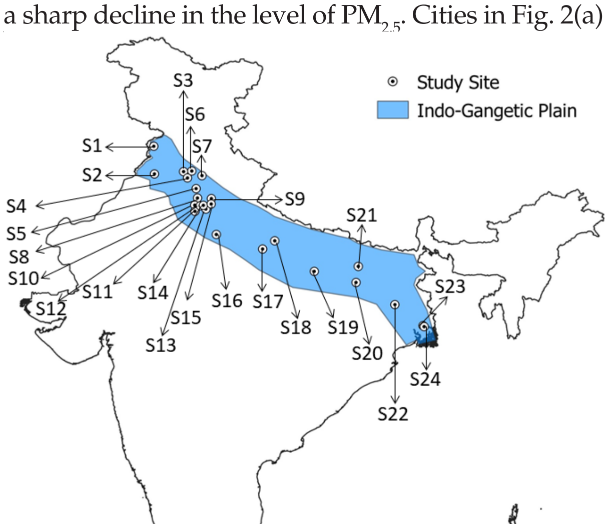

Fig. 1. Selected sites of Indo-Gangetic plain for analysis

Similarly, other cities observed reduction in the $PM_{2.5}$ level in all four phases of lockdown as shown in Fig. 2(b)-(d) ranging reduction level from 30-68%, 23-58%, 8-38%, and -22-15% respectively. Cities (S8-S15) found to follow similarly the pattern of reduction in Phase-1 of $PM_{2.5}$ as rest of other cities, however, in phase-2 and onwards the level rose significantly as compared to other cities whose $PM_{2.5}$ didn't reach its pre-lockdown value before Phase-4. One of the major reasons for the above behaviour is due to more exemption in the transport and industrial activities in those cities Kumar *et al.*, (2020) also observed a significant reduction in $PM_{2.5}$ levels during the first three phases of lockdown period for five Indian cities with high transport and industrial activities: Delhi, Kolkata, Mumbai, Chennai, and Hyderabad.

In addition to that, the sudden rise in the $PM_{2.5}$ level found at the end of each phase of lockdown i.e. 15th April, 4th May, 17th May, and 31st May (unlock phase-1) which shows the resuming activities yield sudden peak in emission which majorly corresponds to transport activities and industrial activities resumption, moreover, it is also found proportional the population density of the city.

Similarly, PM_{10} levels were also found to reduce due to lockdown as shown in Fig. 3 but not significantly as compared to $PM_{2.5}$. One of the main reason of such behaviour is due to harvesting of Rabi crops continued while transport and industrial sector were continued at minimal limited to essential services as detailed by Government guidelines (Ministry of Home Affairs, 2020a, 2020b, 2020c, 2020d). Due to this, the fractional reduction in PM_{10} is less compared to $PM_{2.5}$ apart from the contribution of geological reasons. Another reason that could have contributed to increasing suspended particulates is increased contribution of the residential sector and less removal of road dust due to poor waste management which was also observed by Zambrano-Monserrate *et al.,* (2020). Some cities (S16-18, S20, and S21) do not measure PM_{10} level, hence were not considered for the present analysis. Fig. 3(a) observed a reduction of 25-50%, 1-20%, -20-10%, and -30-10% respectively were observed during Phase-1 to Phase-4 of lockdown. The negative reduction was observed at the end stage of phase-2 when Rabi crop harvest started after the 13^{th} April which is also celebrated as a Baisakhi festival in Northern India. Similarly, in the other cities observed reduction in the PM_{10} level in all four phases of lockdown as shown in Fig. 3(b)-(d) ranging reduction level from 20-59%, 1-29%, -24-

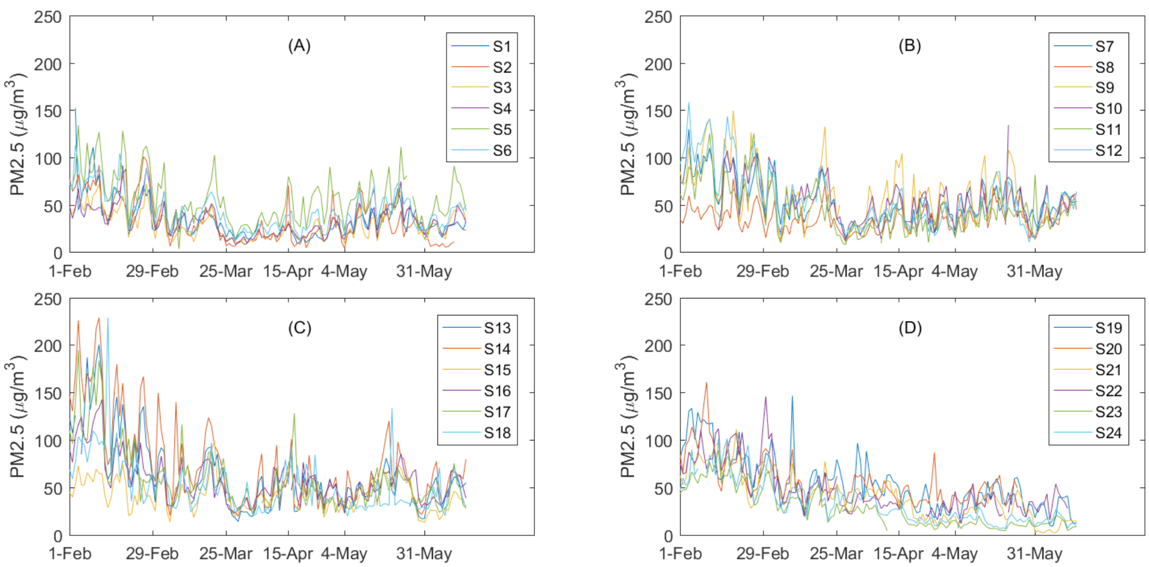

Fig. 2. Variation of PM2.5 level at different study sites (S1-S24) in the IG plain during the four phases of lockdown

Table 1. Detail of the air pollution analysis sites in the Indo-Gangetic Plain

Site no.	Location	Coordinates
S1	Golden Temple, Amritsar, Punjab	31.620, 74.876
S2	Hardev Nagar, Bathinda, Punjab	30.233, 74.907
S3	Model Town, Patiala, Punjab	30.349, 76.366
S4	Ratanpura, Rupnagar, Punjab	30.0325, 76.562
S5	Sector 18, Panipat, Haryana	29.497, 76.993
S6	Patti Mehar, Ambala, Haryana	30.379, 76.778
S7	GobindPura, Yamuna Nagar, Haryana	30.148, 77.289
S8	Murthal, Sonipat, Haryana	29.027, 77.062
S9	Ganga Nagar, Meerut, Uttar Pradesh	28.999, 77.759
S10	Arya Nagar, Bahadurgarh, Haryana	28.670, 76.925
S11	Sector-2 IMT, Manesar, Haryana	28.360, 76.936
S12	MandirMarg, Delhi	28.636, 77.201
S13	Knowledge Park - III, Greater Noida, Uttar Pradesh	28.472, 77.482
S14	Vasundhara, Ghaziabad, Uttar Pradesh	28.660, 77.357
S15	AnandVihar, Hapur, Uttar Pradesh	28.725, 77.749
S16	Sanjay Palace, Agra, Uttar Pradesh	27.198, 78.005
S17	Nehru Nagar, Kanpur, Uttar Pradesh	26.470, 80.322
S18	Central School, Lucknow, Uttar Pradesh	26.882, 80.930
S19	Ardhali Bazar, Varanasi, Uttar Pradesh	25.350, 82.908
S20	Collectorate, Gaya, Bihar	24.795, 84.999
S21	Rajbansi Nagar, Patna, Bihar	25.599, 85.113
S22	Asansol Court Area, Asansol, West Bengal	23.685, 86.945
S23	Belur Math, Howrah, West Bengal	22.629, 88.352
S24	Bidhannagar, Kolkata, West Bengal	22.581, 88.410

14%, and -33-12% respectively.

Further, the level of particulate matters (both $PM_{2.5}$ and PM_{10}) in the lockdown period was compared with the previous years 2018 and 2019 for some of the sites (i.e. S1, S3, S12, S14, S16, S17, and S19) for which archival data were available. During the phase-1 period, the $PM_{2.5}$ level reduced by 15-32%, and the PM_{10} found to decrease by 11-22% when compared during the same period in 2018 and 2019. Similarly, during phase-2 to phase-4, the reduction in particulate matters (both $PM_{2.5}$ and PM_{10}) concentration by 8-27% for these sites were observed compared to previous years (2018, 2019). The lockdown period significantly reduced anthropogenic $PM_{2.5}$ and PM_{10} levels in the air and the remaining $PM_{2.5}$ and PM_{10} post the lockdown reduction could be attributed to the geological causes such as wind erosion. The wind erodes the alluvial soil in IG plain leading to particulate matter emission in the air (Desouza *et al.*, 2015).

CONCLUSION

The effect of lockdown enforced due to COVID-19 pandemic across the Indo-Gangetic plain in India through it, four phases were studied by analysing the concentration of particulate matters (both $PM_{2.5}$ and PM_{10}) during the period of 25th March 2020 to 31st May 2020. The phase-1 saw a maximum drop in the level of $PM_{2.5}$ and till phase-2 it remained below the National Ambient Air Quality Standard (NAAQS) set by CPCB. The change in air quality was also observed in terms of clear skies and plants and looking healthier and greener. The cleaner air with low suspended particulate matter levels benefits the plants allowing them to sequester more dust and carbon-dioxide levels furthering the improvement in air quality parameters. For some cities, it crossed the set Standards, however, for many cities it remained within the ambient air quality standards till the end of Phase-4. The data analysis also indicates that reduction in the traffic load, restricting the usage of vehicles that do not have efficient air filters and enforcing the public to use public transport rather than individual vehicles can help in improving air quality indices. Since geological reasons for particulate matter are hard to eliminate in the IG plain, it is essential to curb anthropogenic particulate matter emission. This could prevent the combined effect of natural and anthropogenic air pollution from reaching toxic levels.

Based on this preliminary study, it is recommended that a change in transport policy and agricultural harvest policy by government intervention is required. Some measures which can be taken in reducing the suspended particulate matter (apart from the green fuel policy) are by setting some no private vehicular days or remote working which can help curb in the transport sector and assist local air quality meet NAAQS. As well as, a strict control measure is required in reducing crop dust and road dust affecting the level of PM_{10} by confined container transport of crop harvest. These measures can be taken especially for Rabi (April-May) and the end period of Kharif (September-

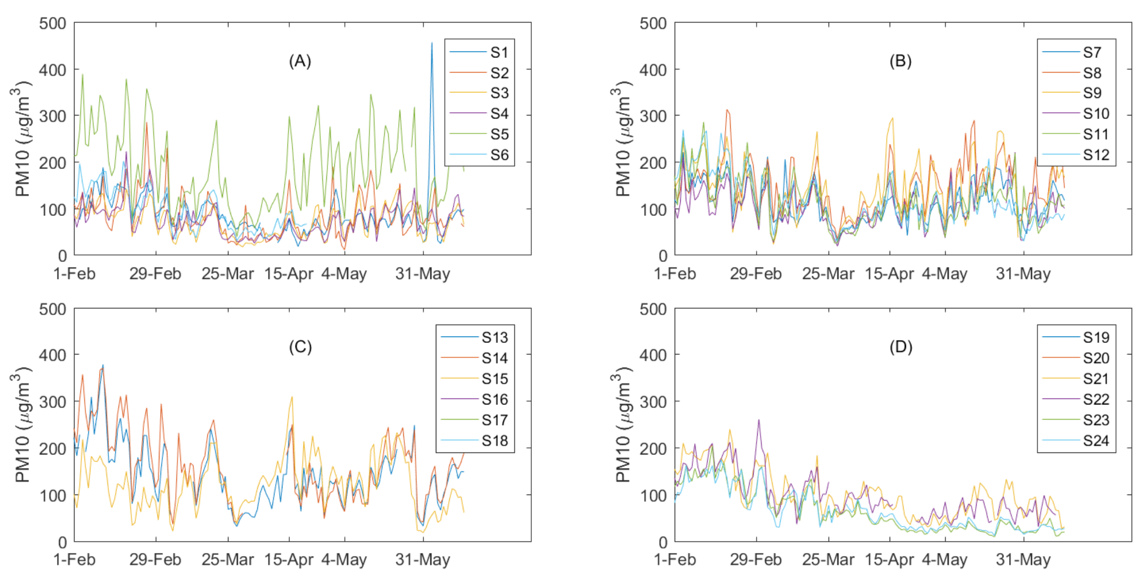

Fig. 3. Variation of PM10 level at different study sites (S1-S24) in the IG plain during the four phases of lockdown.

October) crop harvest. Another policy intervention is required in reducing road dust especially in the summer season (April-June) when the strong hot north-easterly wind blows. Above measurescould bring a transcendental change in the lives of people living in IG plain. It is also recommended to do a comprehensive study on air pollution on a long-term basis in the IG plain rather than a segment local study which has been generally pursued to identify which specific sector-focused policy requires immediate attention.

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REFERENCES

Bao, R. and Zhang, A. 2020. Does lockdown reduce air pollution?' Evidence from 44 cities in northern China. *Sci Total Environ*. 731(1954) : 139052. https://doi: 10.1016/j.scitotenv.2020.139052.

Census, 2011. Primary Census Abstracts, Registrar General of India, Ministry of Home Affairs, Government of India, Available at: http://www.censusindia.gov.in/2011census/PCA/pca_highlights/pe_data.

Cohen, A. J. 2017. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *The Lancet*. 389(10082) : 1907-1918. https://doi: 10.1016/S0140-6736(17)30505-6.

David, L. M. 2019. Premature Mortality Due to PM2.5 Over India: Effect of Atmospheric Transport and Anthropogenic Emissions. *GeoHealth*. 3(1) : 2-10. https://doi: 10.1029/2018GH000169.

Desouza, N. D. 2015. Dust emission from different soil types in the northwest and the Indo-Gangetic Plains of India. *Atmosfera*. 28(4) : 251-260. https://doi: 10.20937/ATM.2015.28.04.04.

Ganguly, T., Kurinji, L. S. and Guttikunda, S. 2020. *How Robust are Urban India's Clean Air Plans?* New Delhi: Council on Energy, Environment and Water.

Kumar, P. 2020. Temporary reduction in fine particulate matter due to "anthropogenic emissions switch-off" during COVID-19 lockdown in Indian cities. *Sustain Cities Soc*. 62(June), p. 102382. https://doi: 10.1016/j.scs.2020.102382.

Kumari, P. and Toshniwal, D. 2020. Impact of lockdown measures during COVID-19 on air quality- A case study of India. *Int J Environ Heal R.*, pp. 1-8. https://doi: 10.1080/09603123.2020.1778646.

Mahato, S., Pal, S. and Ghosh, K. G. 2020. Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India. *Sci Total Environ*. 730: 139086. https://doi: 10.1016/j.scitotenv.2020.139086.

Ministry of Home Affairs, Government of India (2020a) *Guidelines for Phase-1 lockdown (Order number 40-3/2020-D) Dated-24/03/2020*.

Ministry of Home Affairs, Government of India (2020b) *Guidelines for Phase-2 lockdown (Order number 40-3/2020-DM-I(A) Dated-15/04/2020)*.

Ministry of Home Affairs, Government of India (2020c) *Guidelines for Phase-3 lockdown (Order number 40-3/2020-DM-I(A)) Dated-01/05/2020*.

Ministry of Home Affairs, Government of India (2020d) *Guidelines for Phase-4 lockdown (Order number 40-3/2020-DM-I(A)) Dated-17/05/2020*.

Myong, J. P. 2016. Health Effects of Particulate Matter. *The Korean Journal of Medicine*. 91(2) : 106-113. https://doi: 10.3904/kjm.2016.91.2.106.

Narain, S. 2020. *State of India's Environment 2020*.

Ortiz, C. 2017. Evaluation of short-term mortality attributable to particulate matter pollution in Spain. *Environ Pollut*. 224 : 541-551. https://doi: 10.1016/j.envpol.2017.02.037.

Pal, D. K. 2009. Soils of the Indo-Gangetic Plains: Their historical perspective and management', *Curr Sci India*. 96(9) : 1193-1202.

Schepanski, K. 2013. Characterization of dust emission from alluvial sources using aircraft observations and high-resolution modeling. *Journal of Geophysical Research Atmospheres*. 118(13) : 7237-7259. https://doi: 10.1002/jgrd.50538.

Sharma, S. 2020. Effect of restricted emissions during COVID-19 on air quality in India. *Sci Total Environ*. 728 : 138878. https://doi: 10.1016/j.scitotenv.2020.138878.

Srivastava, P. 2015. Soils of the Indo-Gangetic Plains: A pedogenic response to landscape stability, climatic variability and anthropogenic activity during the Holocene. *Earth-Sci Rev*. 140 : 54-71. https://doi: 10.1016/j.earscirev.2014.10.010.

Tribunal, N. G. 2014. *Original Application no. 21 of 2014: Vardhaman Kaushik Vs. Union of India & Ors*.

Tribunal, N. G. 2018.*Original Application No. 681 of 2018: NCAP with Multiple Timelines to Clear Air in 102 Cities to Be Released around August 15.*

Zambrano-Monserrate, M. A., Ruano, M. A. and Sanchez-Alcalde, L. 2020. Indirect effects of COVID-19 on the environment', *Sci Total Environ.*, 728, p. 138813. https://doi: 10.1016/j.scitotenv.2020.138813.