Eco. Env. & Cons. 28 (2) : 2022; pp. (853-862)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i02.041

Which Indian Metropolitan City Poses Highest Human Health Risk from Ambient $PM_{2.5}$?

Dikshant and Lovleen Gupta*[2]

Department of Environmental Engineering, Delhi Technological University, Delhi 110 042, India

(Received 8 August, 2021; Accepted 26 September, 2021)

ABSTRACT

Ambient particulate matter size 2.5μm or less can cause far-reaching health effects in humans. Indian cities routinely experience much higher $PM_{2.5}$ concentrations than the Indian National Ambient Air Quality Standards and World Health Organization standards throughout the year.The objective of the present study is to estimate the short-term and long-term health effects of $PM_{2.5}$ in Indian metropolitan cities namely Delhi, Mumbai, Kolkata, and Chennai for the years 2019 and 2020. The years are chosen to evaluate whether the COVID-induced lockdown had any effect on the mortalities and morbidities associated with ambient $PM_{2.5}$. Health risks were assessed using WHO's AirQ+ v2.0 software.All-cause (natural) mortality (ACNM) and mortality from acute lower respiratory infection (ALRI), chronic obstructive pulmonary disease (COPD), ischaemic heart disease (IHD), lung cancer (LC), cerebrovascular disease (Stroke), and all-cause morbidity natural (ACM) and morbidity from cardiovascular disease(CVD) and respiratory disease (RD) were assessed. The excess number of long-term and short-term effects cases were found to be highest in Delhi for both years, which is 31592and 28688 for ACNM, 284 and 271 for ALRI, 2825 and 2674 for COPD, 3541 and 3309 for LC, 11525 and 11101 for IHD, 11082 and 10557 for Stroke and 28704 and 24643 for ACM, 1153 and 983 for CVD, 6858 and 5862 for RD for 2019 and 2020 respectively.Delhi is the metropolitan city that poses the highest human health risk from ambient $PM_{2.5.}$

Key word *: Air Q+, Cardiovascular Disease, Morbidity, Mortality, Health Effects*

Introduction

Ambient $PM_{2.5}$ concentrations have been related to several health effects, especially on the cardio-respiratory system, according to epidemiological studies (Dockery and Arden, 1994). $PM_{2.5}$is described as particulate matter with an aerodynamic equivalent diameter ≤ 2.5μm(Callen MS, 2012). A study by World Health Organisation (WHO) indicates that $PM_{2.5}$ concentrations are related to 7million global deaths per year, with a strong contribution from the regions of Southeast Asia and the Western Pacific Regions. These deaths are due to ischaemic heart disease stroke (33%), ALRI (8%), (IHD) (36%), COPD (17%), and lung cancer (LC) (6 %)(WHO, 2014).

India has four major metropolitan cities that are New Delhi, Kolkata, Chennai, and Mumbai where the population is more than 4 million in India (Kumar, 2013) as per the latest census record. These areas are heavily inhabited because of heavy industrial and economic activity, which leads to high ambient $PM_{2.5}$ concentrations throughout the year. India's capital city, Delhi has a population of nearly 16.5 million and the annual average concentration (AAC) of $PM_{2.5}$ is always above 100 μgm^{-3} throughout the year in Delhi (Tiwari *et al.*, 2013), which is 10 times the WHO standards. Kolkata, the city in eastern India has a population of around 4.4 million

([2]Assistant Prof.)
ORCID No. 0000-0002-7529-5283

(Office of the registrar general and census commissioner, 2021) and $PM_{2.5}$AAC as 86.12 μgm^{-3} (CPCB, 2017), which is ~8 times the WHO standards. Chennai is the coastal city in southern India having a population of around 4.6 million and $PM_{2.5}$ AAC as 63.15 ≤gm^{-3}(CPCB, 2017), which is ~6 times the WHO standards. Mumbai is the financial capital of India, lies in the central part, and has a population of around 10.3 million and $PM_{2.5}$AAC as 46 μgm^{-3}(CPCB, 2018) which is ~4 times the WHO standards.

Due to the COVID-19 pandemic, these four metropolitan cities were subjected to different lockdown phases during 2020 and have thus experienced lesser $PM_{2.5}$concentrations in 2020. The average reduction in $PM_{2.5-}$ concentration in these metropolitan cities was Kolkata (63.4%) followed by Mumbai (56.4%), Chennai (48.5%), and New Delhi (21.3%) (Ravindra, 2021). This study aims to assess the human health risks attributed to the ambient $PM_{2.5}$ during 2020 (the lockdown period) and compare the findings to those in 2019. This will assist the regulatory bodies in taking appropriate decisions looking at how the human health risks are changing with reducing/controlling $PM_{2.5}$concentrations.

Materials and Methods

Study Area

In this study, we have taken four major metropolitan cities of India that are Delhi (28.7041° N, 77.1025° E), Mumbai (19.0760° N, 72.8777° E), Chennai (13.0827° N, 80.2707° E), and Kolkata (22.5726° N, 88.3639° E) with geographic area 1483 km^2, 603.4 km^2, 426 km^2 and 206.1 km^2 respectively that are shown in Figure 1.

Data collection and analysis

Ambient $PM_{2.5}$ concentration data

For all the four study locations, the 24-hour $PM_{2.5}$ concentration was collected from the CPCB official website(CPCB, n.d.) (https://cpcb.nic.in/) for all the stations mentioned in Table 1 for a given city. The stations chosen for this study were selected based on data availability. The stations where at least 80% of the data during the study period was available were considered. For any given day, the arithmetic average of the $PM_{2.5}$concentration at all the stations in a given city was calculated to arrive at the final $PM_{2.5}$ concentration for that city. The data was collected from January 2019 – December 2020 covering the entire 2 years.

Population Data

Population data were obtained from the Census of India 2011(Office of the registrar general and census commissioner, 2021), and age-wise population data for 2017 was collected from(Global Health Data Exchange, 2021) (http://ghdx.healthdata.org/record/ihme-data/gbd-2017- population-estimates-1950-2017). Based on this data, the population for the years 2019 and 2020 was projected usingthe geometric mean method following Eq. 1:

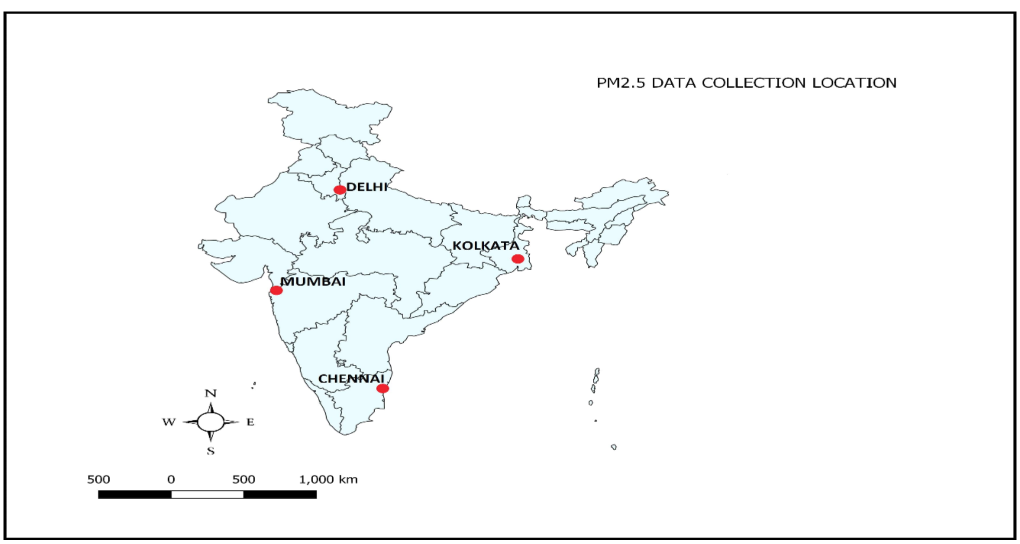

Fig. 1. Study area map with the location of the metropolitan cities.

Table 1. Station Considered for Calculating Annual Average $PM_{2.5}$ 2019 and 2020.

City	Total number of stations	Number of stations considered		Names of stations considered	
		2019	2020	2019	2020
Delhi	40	36	36	Alipur, Anand Vihar, Ashok Vihar, Bawana, CRRI, Dr. Karni, DTU, Dwarka, IGI Airport, IHBAS Dilshad Garden, ITO, Jahangirpuri, JLN, Lodhi Road IMD, Major Dhaynchand, Mandir Marg, Mundka, Najafgarh, Narela, Nehru Marg, North Campus, NSIT, Okhla, Partparganj, Punjabi Bagh, PUSA DPCC, PUSA ITM, RK Puram, Rohini, Shadipur, Sirifort, Sonia Vihar, Sri Aurobindo, Vivek Vihar, Wazirpiur	
Mumbai	19	1	9	Bandra	Bandra, Borivali, Chhatrapati Shivaji Airport, Kurla, Powai, Sion, Vasai, Worli
Chennai	8	3	8	Alandur, Manali, Velachery	Alandur, Arumbakkam, Kodungiyar, Manali Village, Perungundi, Royapuram, Manali, Velachery
Kolkata	7	2	7	RBU, Victoria	Ballygunge, Bidhannagar, Fort William, Jadhavpur, Rabindra Saro, RBU, Victoria

$\{P^o = P(1 + r/100)^n]$ .. Eq. (1)

where P^o is the population at n^{th} decade, P is present population, r is the growth rate, n is no. of the decade. The present population for these cities was taken as the 2011 population. The present population and the projected population are given in Table 2.

Table 2. Population Census Data for the years 2019 and 2020.

City	Population		
	2011	2019	2020
Delhi	16,787,941	19,579,406	19,959,506
Mumbai	12,442,373	13,260,927	13,366,962
Chennai	4,646,732	4,904,443	4,937,646
Kolkata	4,496,694	4,273,837	4,255,311

Human health risk assessment using WHO's AirQ+ Software

Further, AirQ+ is used to evaluate the extent of the effects of air pollution on human health. WHO default measures of Relative Risk (RR) per 10 μgm^{-3} rise of 24-hr average $PM_{2.5}$and baseline incidence (BI) values per 100,000 population is assumed to be associated with the related disease and likely mortality and morbidity as seen in Table 3 (Afghan, 2019). The values for RR and BI were taken from the literature. To find the long-term and short-term effects of air pollution certain values are needed that are air quality data (annual average $PM_{2.5}$ data), population data that are at risk, and health data that are baseline rate of health outcome. A cut-off value is considered for the long term it is 10 μgm^{-3} and for the short term, it is 25 μgm^{-3}(WHO, 2017). The RR is calculated by Eq-2(Mohsen Ansaria, 2018)

$RR = \exp[\beta \ln(x–x^o)]$ Eq. (2)

Whereâ is a confidence interval (95 percent CI) which varies depending on the type of health endpoint, x is pollutant concentration, x^o is the value of counterfactual. The attributable proportion (AP) is the attributed fraction of the health outcome due to exposure in a specific population at a fixed period and can be measured using Eq-3(Mohsen Ansaria, 2018)

$AP = [(RR(c)–1)*p(c)]\backslash[RR(c)*p(c)]$ Eq. (3)

where RR(c) is the relative risk for the health endpoint in the category of exposure (c), and p(c) is the proportion of the population in the category of exposure (c). For a certain baseline incidence (B) of the health outcome chosen In the population, the number of cases per unit population (BE) can be calculated by Eq. (4)(Mohsen Ansaria, 2018).

$BE = B \times AP$ Eq. (4)

N is the size of the population, the number of attributable cases (NE) can be estimated by Eq.(5) (Mohsen Ansaria, 2018).

NE = BE * N .. Eq. (5)

For any of the health result pairs used in the research, AirQ+ used some of the default relative risk values. To evaluate the relative risks of different concentrations, the linear log approach has been used. The excess no. of cases (ENAC) is the Estimated no. of attributable cases evaluated by the AirQ+ software.

ICD: International Classification of diseases; ALRI: Acute lower respiratory infection; COPD: Chronic obstructive pulmonary disease; IHD: Ischaemic heart disease; LC: lung cancer; BI: Baseline incidence per 100000 has been adopted as per WHO default values; GBD: Global burden disease

Results and Discussion

$PM_{2.5}$ trend in Indian metropolitan cities

The 24-hr average $PM_{2.5}$ concentration in four selected metropolitan cities is shown in Figures 2(a), 2(b), 2(c), and 2(d). Highest annual average concentration was observed in Delhi (108.6 ± 84.47 μgm^{-3}), (94.43 ± 79.54 μgm^{-3}) followed by Kolkata (72.31 ± 58.68 μgm^{-3}), (48.69 ± 43.77 μgm^{-3}) and Chennai (46.27 ± 25.91 μgm^{-3}), (30.32 ± 12.69 μgm^{-3}) in 2019 and 2020 respectively. Mumbai has the lowest PM concentration among all the selected cities (32.73 ± 20.89 μgm^{-3}) in 2019 and (37.11 ± 26.74 μgm^{-3}) in 2020. While all the four cities have annual average $PM_{2.5}$ concentrations exceeding the Indian NAAQS standard of 40 μgm^{-3} except Mumbai, but the concentrations in all the four cities exceed the WHO standard of 10 μgm^{-3}.

As per (IMD, 2021) Indian Metrological Department, the seasons are divided as winter (January – February), pre-monsoon (March-May), monsoon (June – September), and post-monsoon (October – December). The order of the seasonal average $PM_{2.5}$ for Chennai, Mumbai, and Kolkata followed: winter

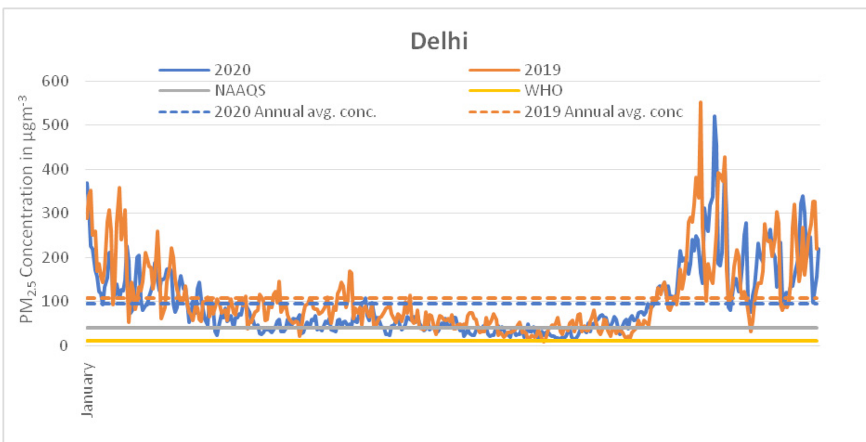

Fig. 2(a). The trend of $PM_{2.5}$ concentration in Delhi in 2019 and 2020.

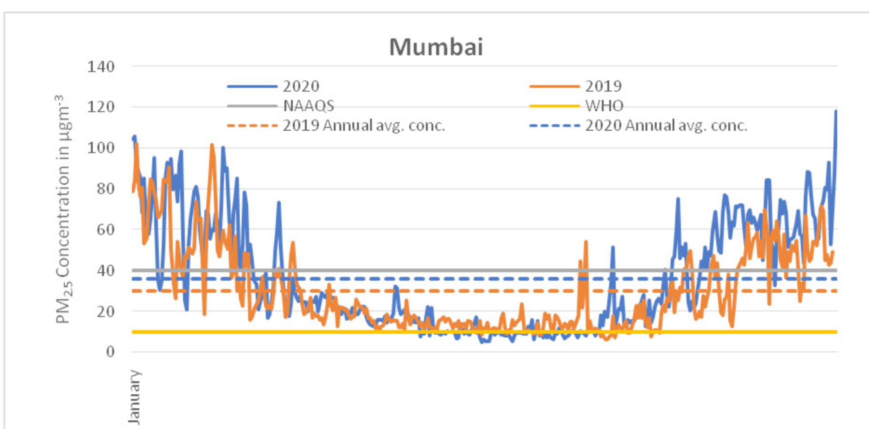

Fig. 2(b). The trend of $PM_{2.5}$ concentration in Mumbai in 2019 and 2020.

> post- monsoon > pre- monsoon > monsoon. However, for Delhi maximum average $PM_{2.5}$ concentration was observed in post-monsoon followed by winter, pre-monsoon, and monsoon having the least concentration through 2019 and 2020.

Long-term effects of $PM_{2.5}$

To determine mortality and morbidity, the annual average concentration of $PM_{2.5}$ and population data of these cities for the years 2019 and 2020 were taken. The values for the BI and RR were taken from Table 3 as per WHO guidelines. The Excess Number of Cases (ENC's) of mortality all (natural) causes (adults age 30+ years) in 2019(Figure 3) is highest in Delhi with a value of 31592 (95% confidence limit of 22647 and 38451) followed by Mumbai with a value 6119(95% confidence limit of 4084 and 7937), Kolkata with value 4822 (95% confidence limit of 3345 and 6040) and least for Chennai with value 3470(95% confidence limit of 2347 and 4446). ENC's in 2020 (Figure 4), in Delhi dropped with value 28688(95% confidence limit of 20307 and 35264) followed by Mumbai with value 7261 (95% confidence limit of 4867 and 9380), Kolkata with value 3197(95% confidence limit of 2168 and 4087) and least in Chennai with value 2085(95% confidence limit of 1388 and 2709).

ENC's of ALRI for children (0-5 years) in 2019 (Figure 3) is highestin Delhi with value 284 (95% confidence limit of 177 and 365) followed by

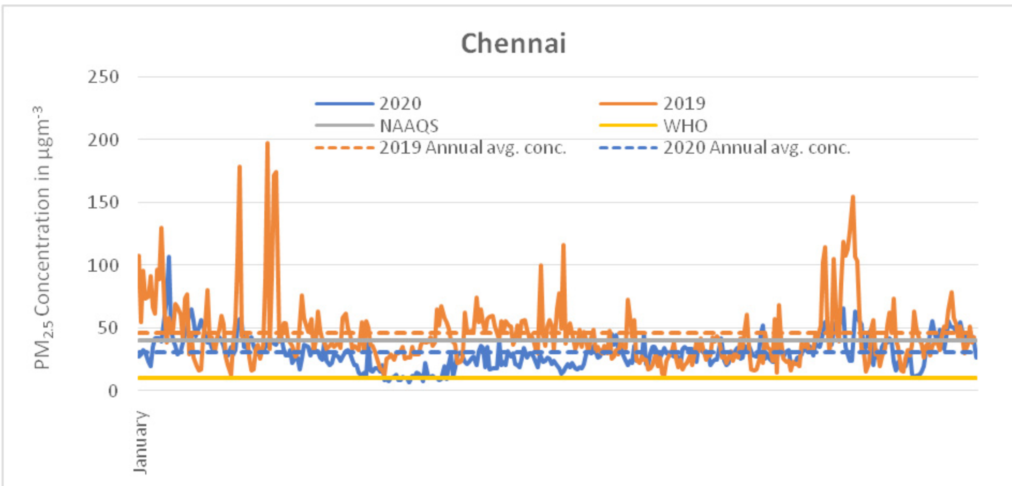

Fig. 2(c). The trend of $PM_{2.5}$ concentration in Chennai in 2019 and 2020.

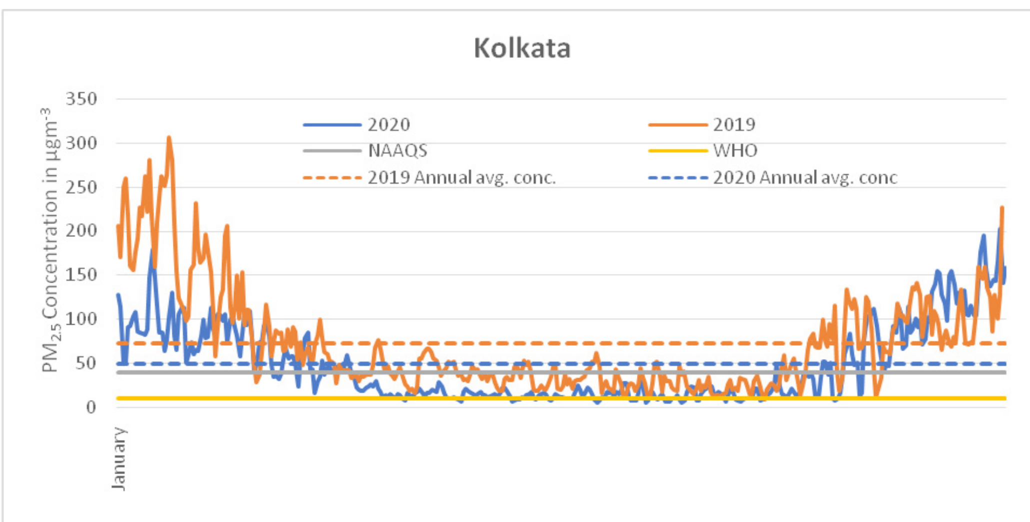

Fig. 2(d). The trend of $PM_{2.5}$ concentration in Kolkata in 2019 and 2020.

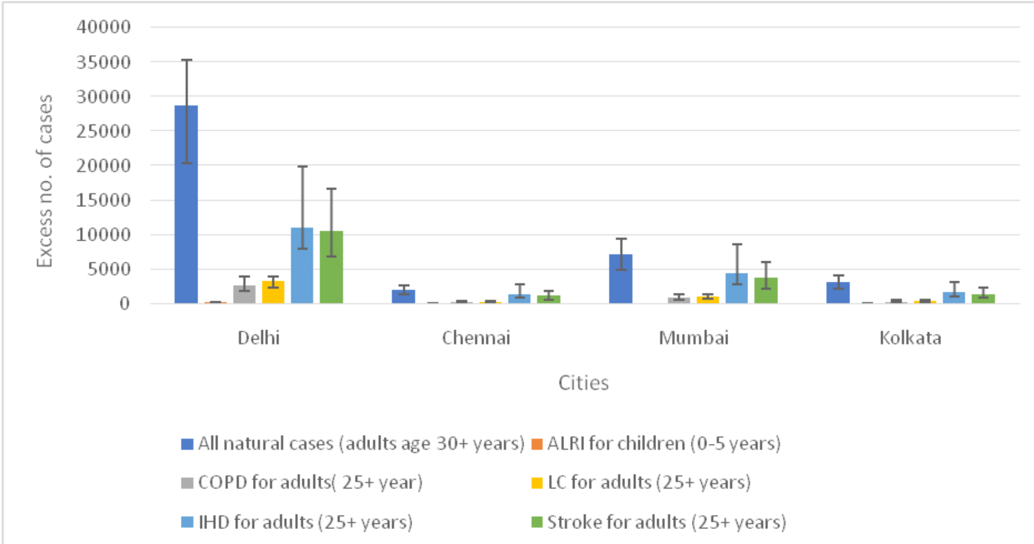

Fig. 3. Mortality due to long-term exposure to $PM_{2.5}$ in 2019

Table 3. World Health Organisation specified default values for RR and BI.

Pollutant	Mortality/ Morbidity	Relative Risk(RR) (95%CI) per 10 $\mu g/m^{-3}$	Baseline Incidence Per 100000 (I)	References
	Long-term effects, cut-off value for $PM_{2.5}$ = 10 μgm^{-3}			
$PM_{2.5}$	Mortality, all natural cases (adults age 30+ years)	1.062(1.04-1.083) GBD 2015/2016	1013	(Omidi Khaniabadi, 2018)
	Mortality due to ALRI for children (0-5 years)	(INTERGRATED FUNCTION 2016) GBD 2015/2016	49	(Omidi Khaniabadi, 2018)
	Mortality due to COPD for adults (25+ year)	(INTERGRATED FUNCTION 2016) GBD 2015/2016	101	(Omidi Khaniabadi, 2018)
	Mortality due to LC for adults (25+ years)	(INTERGRATED FUNCTION 2016) GBD 2015/2016	132	(Omidi Khaniabadi, 2018)
	Mortality due to IHD for adults (25+ years)	(INTERGRATED FUNCTION 2016) GBD 2015/2016	436	(Omidi Khaniabadi, 2018)
	Mortality due to Stroke for adults (25 + years)	(INTERGRATED FUNCTION 2016) GBD 2015/2016	436	(Omidi Khaniabadi, 2018)
	Short-term effects, cut-off value for $PM_{2.5}$ = 25 μgm^{-3}			
	Hospital admission respiratory disease	1.019 (0.9982-1.0402)	1260	(Omidi Khaniabadi, 2018)
	Hospital admission cardiovascular disease including stroke	1.0091 (1.007-1.0166)	101	(Omidi Khaniabadi, 2018)
	Mortality all natural cases 30 + years	1.0123 (1.0045-1.0201)	1013	(Omidi Khaniabadi, 2018)

ICD: International Classification of diseases; ALRI: Acute lower respiratory infection; COPD: Chronic obstructive pulmonary disease; IHD: Ischaemic heart disease; LC: lung cancer; BI: Baseline incidence per 100000 has been adopted as per WHO default values; GBD: Global burden disease

Mumbai with value 85(95% confidence limit of 57 and 110), Kolkata with a value 50 (95% confidence limit of 32 and 65) and least for Chennai with value 43(95% confidence limit of 28 and 56). ENC's in 2020 (Figure 4), in Delhi dropped with value 271(95% confidence limit of 170 and 349) followed by Mumbai with value 96(95% confidence limit of 64 and 125), Kolkata with value 39(95% confidence limit of 25 and 50) and least in Chennai with value 30(95% confidence limit of 20 and 39).

ENC's of COPD for adults (25+ years) in 2019 (Figure 3) is highest in Delhi with a value of 2825(95% confidence limit of 1950 and 4237) followed by Mumbai with a value of 829(95% confidence limit of 507 and 1238), Kolkata with value 490(95% confidence limit of 324 and 734) and least in Chennai with value 413 (95% confidence limit of 263 and 608). ENC's in 2020(Figure 4) in Delhi dropped with value 2674(95% confidence limit of 1832 and 4032) followed by Mumbai with value 938(95% confidence limit of 581 and 1393), Kolkata with value 373(95% confidence limit of 240 and 551) and least in Chennai with value 290(95% confidence limit of 175 and 429).

ENC's of LC for adults (25+ years) in 2019 (Figure 3) is highest in Delhi with a value of 3541(95% confidence limit of 2657 and 4279) followed by Mumbai with a value of 909 (95% confidence limit of 576 and 1241), Kolkata with a value of 590(95% confidence limit of 417 and 739) and least in Chennai with value 473(95% confidence limit of 314 and 618). ENC's in 2020 (Figure 4) in Delhi dropped with value 3309(95% confidence limit of 2425 and 4052) followed by Mumbai with value 1046 (95% confidence limit of 674 and 1404), Kolkata with value 430(95% confidence limit of 288 and 558) and least in Chennai with value 315(95% confidence limit of 197 and 433).

ENC's of IHD for adults (25+ years) in 2019 (Figure 3) is highest in Delhi with a value of 11525 (95% confidence limit of 8391 and 20287) followed by Mumbai with a value of 3990 (95% confidence limit of 2556 and 7904), Kolkata with value 2107(95% confidence limit of 1471 and 3888)and least in Chennai with value 1889(95% confidence limit of 1258 and 3629). ENC's in 2020 (Figure 4) in Delhi dropped with value 11101 (95% confidence limit of 7954 and 19869) followed by Mumbai with value 44322(95% confidence limit of 2880 and 8660), Kolkata with value 1694 (95% confidence limit of 1135 and 3241) and least in Chennai with value 1407(95% confidence limit of 895 and 2805).

ENC's of Stroke for adults (25+ years) in 2019 shown in (Figure 3) is highest in Delhi with value 11082(95% confidence limit of 7303 and 17357) followed by Mumbai with value 3475 (95% confidence limit of 1881 and 5386), Kolkata with value 1961 (95% confidence limit of 1222 and 3137)and least in Chennai with value 1694 (95% confidence limit of 994 and 2676). ENC's in 2020 (Figure 4) in Delhi dropped with value 10557(95% confidence limit of 6835 and 16628) followed by Mumbai with value 3901(95% confidence limit of 2186 and 6108), Kolkata with value 1526 (95% confidence limit of 902 and 2419) and least in Chennai with value 1219(95% confidence limit of 652 and 1898).

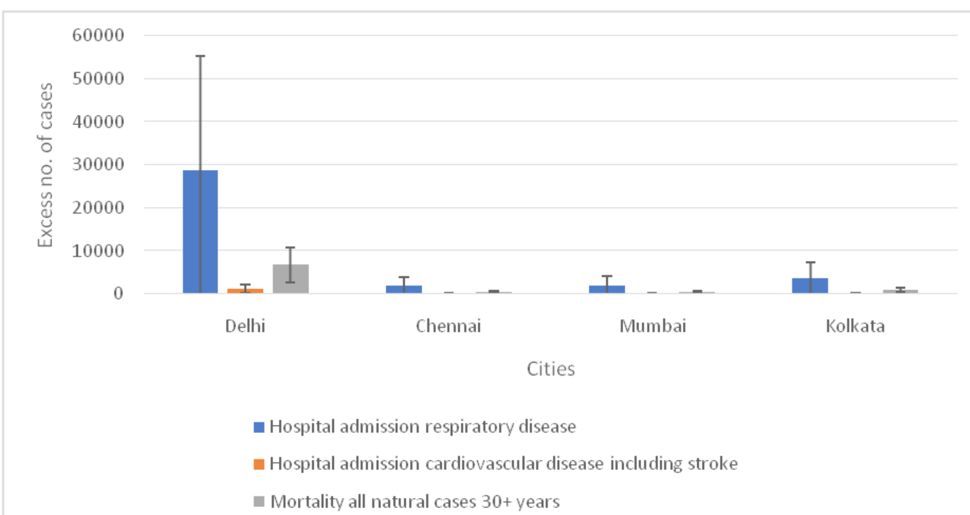

Fig. 4. Mortality due to long-term exposure to $PM_{2.5}$in 2020

The ENC's value is highest in Delhi due to the highest $PM_{2.5}$ concentration of 108.50 μgm^{-3} out of all the four metropolitan cities and ENC's values declined in 2020 due to a decline in PM concentrations. However, there is no decline in ENC noticed in Mumbai from 2019 to 2020 as the $PM_{2.5}$ concentration also did not decline.

Short-term effects of $PM_{2.5}$

The ENC's of hospital admission respiratory disease in 2019 (Figure 5) is highest in Delhi (28704 and 95% CI: 0-55347) followed by Mumbai (1933 and 95% CI: 0-4015), Kolkata (3671 and 95% CI: 0- 7329) and least in Chennai (21940 and 95% CI: 0-3975). ENC's in 2020 (Figure 6) in Delhi dropped with value (24643 and 95% CI: 0-48149) followed by Mumbai (3037 and 95% CI: 0-6281), Kolkata (1879 and 95% CI: 0-3840), and least in Chennai (529 and 95% CI: 0-1102).

The ENC's of hospital admission cardiovascular disease including stroke in 2019 (Figure 5) is highest in Delhi (1153 and 95% CI: 223-2032) followed by Mumbai (75 and 95% CI: 14-136), Kolkata (145 and 95% CI: 28- 259) and least in Chennai (76 and 95% CI: 14-136). ENC's in 2020 (Figure 6) in Delhi dropped with value (983 and 95% CI: 189-1742) followed by Mumbai (118 and 95% CI: 22-213), Kolkata (73 and 95% CI: 14- 132), and least in Chennai (20 and 95% CI: 04-37). The ENC's of mortality all-natural cases 30+ years in 2019 shown in (Figure 5) is highest in Delhi (6858 and 95% CI: 2601-10820) followed by Mumbai (451 and 95% CI: 166-731), Kolkata (867 and 95% CI: 324- 1386) and least in Chennai (454 and 95% CI: 168-734). ENC's in 2020 (Figure 6) in Delhi dropped with value (5862 and 95% CI: 2211-9296) followed by Mumbai (709 and 95% CI: 262-1149), Kolkata (440 and 95% CI: 163-710), and least in Chennai (123 and 95% CI: 45-200).

Comparison of our results to the studies carried out in the past

In comparison to the previous studies (Table 4), our results are slightly less despite the fact that at the time those respective studies were carried out, the $PM_{2.5}$ concentration was higher (AAC of $PM_{2.5}$ is 131.5 mgm^{-3} in Delhi and 68.5 mgm^{-3} in Mumbai (Deshpande, 2016), 32.62 ± 16.63 mgm^{-3} in Chennai and 102.96 ± 85.38 mgm^{-3} in Delhi (Srimuruganandam, 2019), and 111.7 mgm^{-3} in Delhi (Afghan, 2019). This may be attributed to the fact that has considered the total population of the city and we have considered age-wise population for more accuracy (5^+, 25^+, and 30^+ years population). For Kolkata, however, no such study has been carried out in the past.

Limitations

The RR values used in this analysis are rationally established in the USA, but there would be a lot of uncertainty if RR values are observed in certain other countries, such as India because atmospheric conditions and the economy vary considerably. We have considered that 80% of the population is susceptible to emissions, although it may be high or low, and the degree of indoor pollution is different

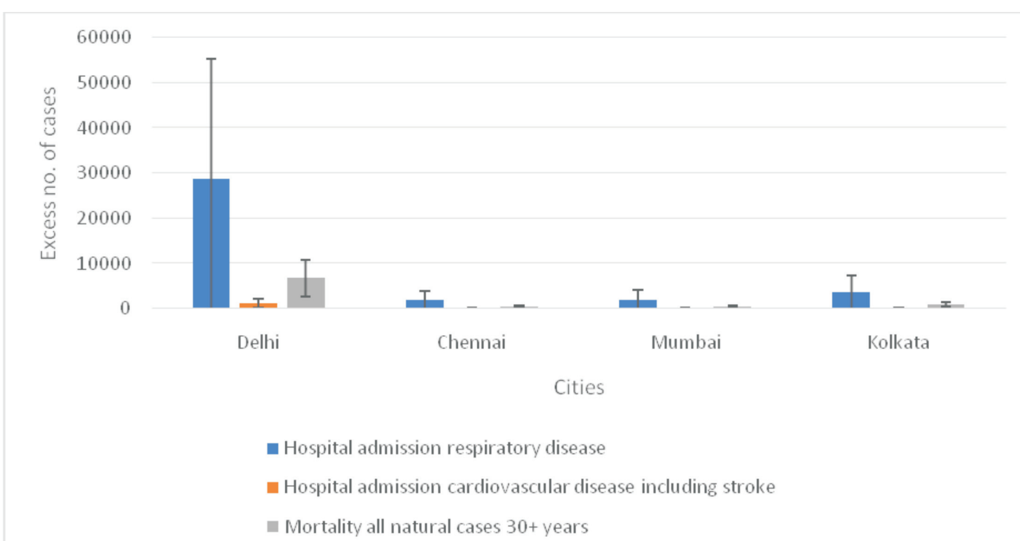

Fig. 5. Morbidity due to short-term exposure to $PM_{2.5}$ in 2019.

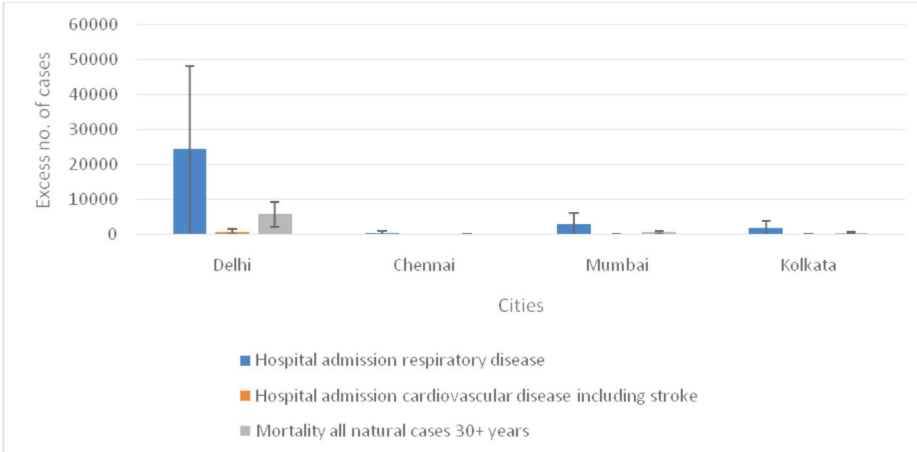

Fig. 6. Morbidity due to short-term exposure to $PM_{2.5}$ in 2020.

Table 4. Comparison of results between present and previous studies.

S. No.	City	Results from our study				Results from past studies			
		Long term effects		Short term effects		Long term effects	Short term effects	Year of study	Reference
		2019	2020	2019	2020				
						9,968	-	2015	(Deshpande, 2016)
1.	Delhi	31,592	28,688	28,704	24,643	40,000	38,211	2017	(Srimuruganandam, 2019)
						72,254	45,000	2018	(Afghan, 2019)
2.	Mumbai	6,119	7,261	1,933	3,037	8,341	-	2015	(Deshpande, 2016)
3.	Chennai	3,470	2,085	1,940	1,529	12,000	4,135	2015	(Srimuruganandam, 2019)

and can have different exposure values. In 2020 lockdown is imposed in India due to this pollution level as well the population exposure to PM might be below. There are also potential pitfalls in the precision of the data given by CPCB, such as power loss, labour unavailability, human error, error in control, and inadequacy of the air quality monitoring infrastructure.

Conclusion

In the present analysis, human health impacts on mortality and morbidity were measured inDelhi, Mumbai, Chennai, Kolkata during 2019 and 2020, taking into account 80 percent of the total population at risk of air pollution exposure of the parameters $PM_{2.5}$ pollutant using WHO's AirQ+ v2.0 software. Delhi is the metropolitan city that poses the highest human health risk from ambient $PM_{2.5}$. The ENC's value is high in Delhi due to a high $PM_{2.5}$ concentration of 108.50 μgm^{-3} and ENC's values declined in 2020 due to a decline in PM concentrations in all cities except Mumbai. But there is a big gap, and the downturn is due to the lockdown in India in 2020. We may also infer that higher amounts of $PM_{2.5}$ and higher demographics prone to air pollution can contribute to more cases and hospital admission. Some preventive measures should be taken by the government to monitor the rise in air pollution. Popular mitigation measures for all four cities will have a negative effect. City-specific measures can also be efficient at enforcing and reducing PM concentrations.

Acknowledgment

We gratefully acknowledge the Central Pollution Control Board (CPCB) of India for providing daily particulate matter data. We would also like to thank the Office of the Registrar General and Census Commissioner, the Indian Ministry of Home Affairs, the Government of India for providing Indian Census data for each metropolitan city.

Conflicts of interest

The author declares no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Afghan, F.R. 2019. Health Impacts Assessment due to $PM_{2.5}$, PM_{10} and NO_2 Exposure in National Capital Territory (NCT) Delhi. *Pollution.* 6 (1) : 115-126.

Callen, M.S. L.J. 2012. Apportionment of the airborne PM10 in Spain. Episodes of potential negative impact for human health. *Journal of Environmental Monitoring*. 14 (4) : 1210-1219.

CPCB. (n.d.). Retrieved from CPCB: https://cpcb.nic.in/

CPCB, 2017. *CPCB*. Retrieved from Ministry of Environment, Forest and Climate Change, Govt. of India: https://cpcb.nic.in/automatic-monitoring-data/

CPCB, 2017. *CPCB*. Retrieved from Ministry of Environment, Forest and Climate Change, Govt. of India: https://cpcb.nic.in/manual-monitoring/

CPCB, 2018. *CPCB*. Retrieved from https://cpcb.nic.in/manual-monitoring/

Deshpande, K.J. 2016. Disability-adjusted life years and economic cost assessment of the health effects related to PM2.5 and PM10 pollution in Mumbai and Delhi, in India from 1991 to 2015. *Environmental Science and Pollution Research.* 24 : 4709-4730.

Dockery, D. and Arden, 1994. Acute respiratory effects of particulate air pollution. *Annual Review of Public Health.* 15 : 107-132.

Evaluation, I.F. 2021. *Global Health Data Exchange*. Retrieved from http://ghdx.healthdata.org/record/ihme-data/gbd-2017-population-estimates-1950-2017

IMD, 2021. *Indian Metrological Department, Ministry of Earth Sciences, Government of India*. Retrieved from Ministry of Earth Sciences, Government of India: https://mausam.imd.gov.in/

Kumar, K.H. 2013. Comparison of research productivity between metro and non-metro cities in a biomedical journal from India. *Annals of Medical and Health Sciences Research.* 3 (2) : 182-186.

Mohsen Ansaria, M. H. 2018. Meteorological correlates and AirQ+ health risk assessment of ambient fine Particulate Matter in Tehran, Iran. *Environmental Research.* 170 : 141-150.

Office of the registrar general and census commissioner, I. 2021. *Office of the Registrar General and Census Commissioner, India*. Retrieved from censusindia.govt: https://censusindia.gov.in/2011-common/censusdata2011.html

Omidi Khaniabadi, Y.S. 2018. Air quality modeling for health risk assessment of ambient PM10, PM2.5 and SO2 in Iran. *Human and Ecological Risk Assessment: An International Journal*. 25 (5) : 1298-1310.

Ravindra, K.S. 2021. Impact of COVID-19 lockdown on ambient air quality in megacities of India and implication for air pollution control strategies. *Environmental Science and Pollution Research.* 28 : 21621–21632.

Srimuruganandam, N.M. 2019. Health effects of particulate matter in major Indian cities. *International Journal of Environmental Health Research*. 31 (3) : 258-270.

Tiwari, S., Srivastava, A. K., Bisht, D. S., Parmita, P., Srivastava, M. K. and Attri, S.D. 2013. Diurnal and seasonal variations of black carbon and PM2.5 over New Delhi, India: Influence of meteorology. *Atmospheric Research*. 125-126 : 50-62.

WHO, 2014. *World health organization releases 7 million premature deaths annually linked to air pollution.* Retrieved from https://www.who.int/mediacentre/news/releases/2014/air-pollution/en/

WHO, 2017. *Evolution of WHO air quality guidelines: past, present and future.* Copenhagen: Copenhagen: WHO Regional Office for Europe, 39.