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ASSESSING THE HEALTH IMPACT OF PARTICULATE MATTER USING AirQ+

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Abstract: Air pollution has adverse effects on the well-being of individuals. To address this issue, the World Health Organization (WHO) has developed a software tool called AirQ+ for assessing the health risks which are associated with exposure to pollutants. In understanding and mitigating the impact of air pollution on individuals and communities, this tool serves as an essential resource. In this study, AirQ+ was used for assessing impact on health due to $PM_{2.5}$ for year 2018 to 2022 in North-West Delhi. Four cases were taken i.e., Mortality caused due to all natural cases (ANCs) (in adults having age above 30 years), Mortality due to lung cancer (LC) for adults, Mortality due to Chronic Obstructive Pulmonary Disease (COPD) for adults (30+ year) and Mortality due to ischemic heart disease (IHD) for adults (25+ years). Highest number of cases were found in 2018 which were 17747, 1160, 1405 and 6227 for mortality due to ANCs, LC, COPD and IHD respectively. Lowest number of cases were reported in the year 2020. By taking complete average of five years these values were obtained as 16272, 1141, 1318 and 6211 for mortality due to ANCs, LC, COPD and IHD respectively. AirQ+ can be used by public health authorities and researchers to make decisions regarding air quality improvement measures.

Keywords: AirQ+, COPD, WHO, $PM_{2.5}$, IHD.

I. Introduction:

Air pollution is the existence of substances within atmosphere which are harmful for environment and human health. These are usually caused by natural processes or activities of human. These harmful substances i.e., pollutants include gases, particles (small particles or liquids), biological and chemical substances. Human health, environment and ecosystems are affected by these pollutants. Agriculture, smoke from chimneys, emission from industries, emission of gases from home appliances like refrigerators, ovens, air conditioners, etc. and the burning of fossil fuels in electricity generation are some primary sources of air pollution. Due to these activities some pollutants such as carbon monoxide, nitrogen oxides (NO_x), sulfur dioxide, particulate matter (PM) and volatile organic compounds release into air.

Many health problems, including respiratory diseases, allergies, asthma, an elevated mortality rate, and even premature deaths are caused due to exceedance of the pollutants beyond a certain threshold limit in the atmosphere. (Rounce et al., 2012). As per WHO, pollution in the air is responsible for approximately one-third of deaths caused by conditions such as lung cancer, heart disease and stroke. Thus, pollution in air in India is a major issue to be looked into. The impact of fine particulate matter ($PM_{2.5}$) on well-being of individuals has come into focus due to increase in premature death associated with air pollution (Lo et al., 2023; Cohen et al., 2017). Since, $PM_{2.5}$ particles are of such small size that they can penetrate deeply into the lungs and also can go into bloodstream, hence they are major point of concern. Consequently, a range of health problems, including cardiovascular ailments, premature mortality, respiratory issues and lung cancer can arise. For children, senior citizens, and individuals with pre-existing health conditions such a high level of $PM_{2.5}$ are dangerous and may also be fatal sometimes. Particulate matter contains particles that can adversely affect the respiratory system include dust, soot, smoke, pollen, and liquid droplets. A variety of respiratory symptoms, such as irritation of the airways, compromised lung function, irregular heart rate, breathing difficulties and an increased risk of heart attack, stroke-related diseases, and asthma can be induced due to exposure to PM. (T. Xayasouk et al.2020). In the year 2012, the reason for approximately 30 lakh deaths was air pollution, as per WHO. Also, the number of attributable deaths rises to around 6.5 million, which are approximately 11.6% of all global deaths, when we consider both indoor and outdoor air pollution together (WHO, 2016a). Therefore, it is important to calculate the impact of pollution and changes resulting from the implementation of policies to support policy makers' decisions. For quantifying the health impacts occurring because of air pollution, $AirQ^+$ model is used which is developed by WHO.

$AirQ^+$ is a software tool that integrates various air quality models and techniques to predict and assess air quality levels. It was developed by WHO and has various applications in management of air quality and forecasting studies across the world. The software provides a user-friendly interface and allows for the integration of data from multiple sources, such as air quality monitoring stations and meteorological stations. AirQ+ quantifies the consequences of air pollution on mortality and morbidity through population attributable fraction (PAF). The PAF represents proportionate reduction in morbidity or mortality of population that would be observed if unveiling to air pollution were decreased to a less harmful risk scenario. (WHO, 2016b), e.g., Threshold limits of pollutants by WHO (annual average limits 10 $\mu g/m^3$ for $PM_{2.5}$ (WHO, 2006)). This information can be used to inform public health policies and interventions which aims to reduce exposure to air pollutants. Gurjar et al. (2010) used the AirQ+ and the Ri-MAP model to calculate effect on health related to morbidity and mortality in National Capital Territory of Delhi for years 1998 to 2005. Miri et al. (2016) used the AirQ+ to calculate effect on well-being of human associated with criteria air pollutants like $PM_{2.5}$, SO_2, PM_{10}, NO_2 and O_3 of Mashhad (Iran). Their study focused on assessing various health outcomes, including respiratory and heart diseases mortality, hospital entries related to cardiovascular diseases (CVD), acute myocardial infarction, respiratory diseases (RD) and COPD. The research aimed to calculate effects of these criteria air pollutants on public health. Similarly, Gholampour et al. (2014) have also utilized AirQ+ for calculating the effects of exposure to PM and health effects associated with it in Tabriz, Iran. They have considered urban and industrial regions. Similarly, Nagpure et al. (2014) utilized data on, nitrogen dioxide (NO_2), total suspended particulates (TSP) and sulfur dioxide to evaluate health impacts on human, including mortality and morbidity, in the National Capital Territory (NCT) of Delhi. They employed the AirQ+ software and the Ri-MAP Excel spreadsheet model for the years 1991 to 2010. The study focused on calculating the consequences of these pollutants on public health in NCT Delhi region. Skotak and Swiatczak (2008) have also done the calculation of impact on health using AirQ+ caused due to unveiling to PM_{10} in Poland. They found health risks in industrial zone of Southern Poland. The present study aims to calculate the potential risks that particulate matter poses on human health using AirQ+ software.

II. Instrumentation and Methods:

2.1 Site Description:

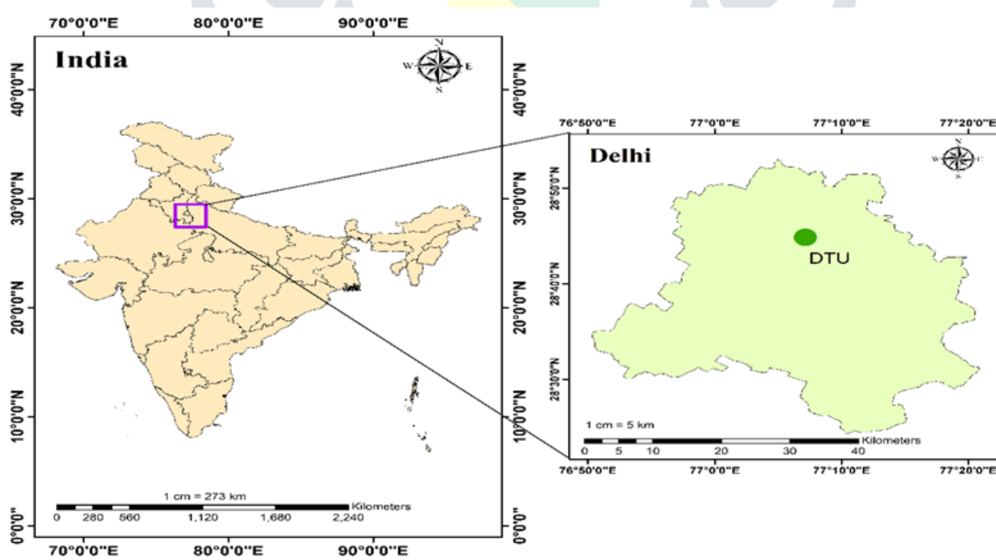

Fig.1. Study area map indicating geographical location

Due to rapid increase in population (approximately 16.8 million as per report of census 2011), urban development, industrial development, rapid increase in the vehicles on road and rise in energy demand, New Delhi has come in the list of the most adversely affected cities due to pollution in the world (Sharma et al., 2017). Delhi, situated at approximately 28.7041° latitude and 77.1025° longitude, and having an elevation of 216 meters above MSL, serves as India's national capital. It is located approximately 160 kilometers to the south of the Himalayan Mountain range. (Saksena et al., 2009). It has an area of about 1484 km^2. According to the reports of Census of India, 2011, population density of Delhi is 11,312 individuals in square kilometer area. The city faces intense summers, moderate rainfall, and cold winters. Delhi shares boundaries with states of Uttar Pradesh and Haryana. As per Delhi Economic Survey 2018-19, total number of automobiles in Delhi, by March 2018, reached to a total figure of 10.9 million, in which two wheeled vehicles were approximately 7 million. (Planning Department, Government of NCT Delhi, 2019). The traffic congestion was increased due to this immense increase in vehicles and this further results in increase in pollution in air (Advani & Tiwari et al., 2005).

Delhi region has subtropical semi-arid (steppe) climatic conditions with an annual average precipitation value of 611.8 mm and an annual mean temperature value of 31.5 °C. This city has average number of pollution episodes as 15 per year and has more than 200 days of $PM_{2.5}$ exceedances of NAAQS limits (Singh et al., 2021). It has a varied climate with four different seasons i.e., Winter season, Autumn season, Summer season, and Rainy season with January being the coldest month, May/June being the hottest month with a average annual rainfall of about 70 cm.

2.2 Data collection:

In this work, data is collected from the official website of CPCB for the monitoring station at DTU, New Delhi. The time period selected is 1 January 2018 to 31 December 2022. Data of $PM_{2.5}$ was collected from CPCB website and it was used for assessing health risk using AirQ+. The Central Pollution Control Board (CPCB) is running an initiative throughout India called the National Air Quality Monitoring Programme (NAMP). This initiative leads setting up 804 monitoring stations across 344 urban centers and municipalities in 28 states and 6 UTs. These stations continuously track the concentrations of four distinct air pollutants: nitrogen dioxide, respirable suspended particulate matter (commonly known as PM having diameter of 10 μm or less - PM_{10}), sulfur dioxide and fine particulate matter having diameter of 2.5 μm or less ($PM_{2.5}$). In order to effectively carry out NAMP, CPCB has partnered with state pollution control boards, relevant committees, and the NEERI which is National Environmental Engineering Research Institute. This combined effort leads to evaluate air pollution concerns across various locations, identify urgent problem areas, and provide useful information for managing and enhancing air quality. NAMP has an important role in decision-making by providing the required data to help keeping safe health of the people and the environment. CPCB has set large number of Continuous Ambient Air Quality Monitoring Stations (CAAQMS) in various significant cities in India. These stations continuously measure criteria pollutants throughout the year. The stations use analyzers that are according to USEPA Automated Federal Equivalent Method (FEM) standards for monitoring of PM_{10} and $PM_{2.5}$

2.3 AirQ+ Software:

AirQ+ is developed by WHO for calculation of health impacts caused by various pollutants. It is employed for calculating the consequences of coming in contact with air pollution on health of public. Calculations performed in AirQ+ depends on methodologies obtained through epidemiological studies and concentration-response functions (Bahrami Asl et al., 2018). It can calculate both the long and short-term impacts. To quantify effects of exposure to $PM_{2.5}$, inputs were given like average value of each year; $PM_{2.5}$ between the years 2018 to 2021; cut-off value of $PM_{2.5}$ suggested by WHO (WHO 2021b); values which quantifies at risk population; baseline incidences per 100,000 population and various health end points and also whole population etc. The input data which are optional for AirQ+ may include parameters like latitude, longitude, area size and location.

AirQ+ uses an Attributable Proportion (AP) function to assess the consequences of PM exposure. AP is proportion of health impacts within a specified inhabitants that can be attributed to coming in contact to pollutant of air, presuming a relation in the health problem and exposure and no major factors affecting this relationship.

$$AP = \frac{\sum(\mathrm{RR} - 1) \times P_e}{\sum \mathrm{RR} \times P_e} \quad (1)$$

Here, RR is used to denote relative risk, P_e is fraction of the population under exposure. The main factors influencing health outcomes are the relative risk (RR) and baseline incidence (BI). Relative risk represents the probability of disease occurrence within the group which is exposed (P_{DE}) compared to those not in direct contact i.e., exposed (P_{DU}). This can be expressed as P_{DE}/P_{DU}.

RR because of pollution in air are simply modelled using a log-linear function,

$$RR = \frac{e^{(\alpha + ßX)}}{e^{(\alpha + ßXo)}} = e^{(ß(X - Xo)} \quad (2)$$

Here, X denotes concentration of pollutants in μg/m^3, and X_o denotes the value of cut-off, ß denotes how much change in the RR occurs due to unit change in X.

Distribution of population exposure has to be determined in the stage of assessing exposure, and RR for a specific outcome related to health can be derived by utilizing exposure-response function which are found by epidemiological studies. Relative risk coefficients for a number of health outcomes are pre-defined. Knowing or assuming some baseline frequency of chosen endpoint of health in taken population, B, then B_E, number of occurrences in unit population due to selected condition of exposure E in the population, is found out by:

$$B_E = \text{B} \times \text{AP} \tag{3}$$

For any population having specific size N, estimated number of cases which are attributed to E,

$$N_E = B_E \times N \tag{4}$$

Frequency of outcome in that population which are not exposed can be calculated as:

$$BN_E = \text{B} - B_E \tag{5}$$

$$BN_E = \text{B} \times (1 - \text{AP}) \tag{6}$$

The RR values utilized in AirQ+ software are taken from data files expanded by the WHO European Centre for Environment and Health. These values are derived from a large number of peer-reviewed studies conducted to analyze the connection between pollution in air and particular health related consequences. (Khaniabadi et al., 2017a; Khaniabadi et al., 2017d; Khaefi et al., 2016; Khaniabadi et al., 2017b). In this, the estimation process is carried out on the basis of proportion of attributable population. This proportion is defined as the fraction of the health outcome within a specified population that can be associated to a specific atmospheric pollutant exposure during a specific timeframe (Omidi et al., 2016; Fattore et al., 2011).

In this work, AirQ+ v.2.2 developed by WHO was utilized to calculate the impact on health due to $PM_{2.5}$ for year 2018 to 2022. Population data for this analysis was acquired from the website of the Registrar General & Census Commissioner, India. This website operates under Ministry of Home Affairs, Government of India. Default value of RR was accepted from AirQ+ software and a cut-off value for $PM_{2.5}$ is accepted as 10 µg/m^3, recommended by WHO. Baseline values were retrieved from past research works and finally various mortality due to different causes were calculated.

III. Results and Discussion:

3.1 Study of Annual Variation:

The values of $PM_{2.5}$ were obtained from CPCB website and plotted to obtain an annual average for every year from 2018 to 2022. Maximum value of $PM_{2.5}$ was obtained for the year 2018 (128.7 µg/m^3) and minimum value was obtained for the year 2022 (96.1 µg/m^3) as shown in **Fig.2**. There is a decrease in values from year 2018 to 2020 and again rise in 2021. The decrease in values of $PM_{2.5}$ in the year 2020 can be attributed to nationwide lockdown imposed by Indian Government in 2020 due to COVID-19. This lockdown resulted in shutting down of industries and factories for some duration (Shouraseni et al., 2021). This value again rises to 118.9 µg/m^3 in year 2021 and falls again in 2022.

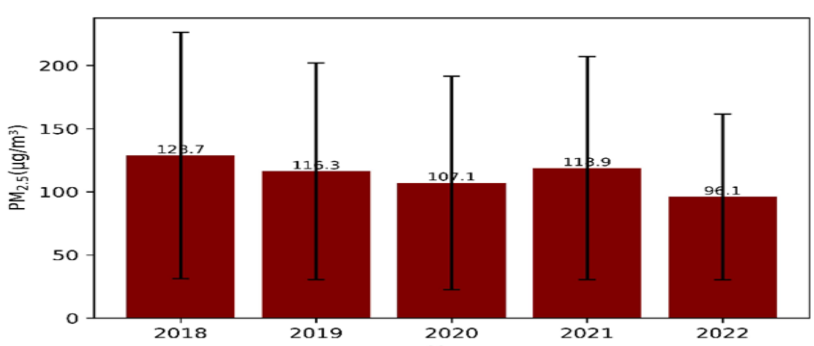

Fig.2. Annual variation of $PM_{2.5}$

3.2 Analysis of Impact on Health:

For doing the health impact analysis, we have used the software of AirQ+ developed by WHO. In this work, long term impact assessment due to $PM_{2.5}$ is done in Mortality caused due to all natural cases (ANCs) (in adults having age 30+ years), lung cancer (LC) for adults, COPD for adults (30^+ year) and IHD for adults (25+ years).

These mean values of every year are used for finding the impact for the years 2018-2022. After that, a complete five years mean is also used to do the analysis. Since the station is situated in North-West Delhi, the data related to population was collected from the census of India 2011 website which was obtained as 36,56,539. As per this, at first the results were calculated for the year 2018 in which we obtained mortality, ANCs due to $PM_{2.5}$ long-term effects were found to be highest with value of 17747 and taking confidence limit of 95% we got values 14794- 18978. The estimated number of attributable cases for mortalities ANCs causing by long term exposure of $PM_{2.5}$ were 16557, 15597, 16816, and 14357 in years 2019, 2020, 2021, and 2022, respectively. When calculated by taking five years average, attributable cases of mortality due to ANCs was 16272, annually. Gurjar et al., in 2010, did a study to calculate the estimated number of cases (ENCs) related to total mortality in NCT, which has population of approximately one million, varying from 750-930 in the years 1998 to 2005. When calculating Mortality due to LC for adults, again highest number of cases were obtained for the year 2018 (1160). For the next four years it was 1145, 1129, 1149 and 1104 respectively. When calculated by taking five years average, it was obtained as 1141 annually.

Table 1. Result of AirQ+ showing mortality due to different causes taken for the year 2018 to 2022

S. No.	Year	Mortality, ANCs (adults age 30+ years)	Mortality due to LC for adults	Mortality due to COPD for adults (30+ years)	Mortality due to IHD for adults (25+ years)
1.	2018	17747	1160	1405	6227
2.	2019	16557	1145	1335	6214
3.	2020	15597	1129	1277	6204
4.	2021	16816	1149	1350	6217
5.	2022	14357	1104	1202	6187

The estimated number of attributable cases of COPD in Adults having age above 30 years mortality were taken which are in long-term contact to $PM_{2.5}$. Maximum number of ENCs was found in 2018 as 1405 and minimum number of ENCs were in 2022 having value of 1202. The ENCs due to mortality because of COPD were 1335, 1277, and 1350 in years 2019, 2020, and 2021, respectively. By taking five years average it was obtained as 1318. It was reported by Gurjar et al. (2010) that the Estimated Number of Cases (ENCs) related to mortality due to COPD fell ranging within 105 to 130, with confidence interval of 95%, during the period 1998 to 2005 in NCT, Delhi. As per Nagpure et al. (2014) these values of ENCs were 12809, 16253 and 26525 in the year 1991, 2000 and 2010, respectively.

Estimated number of attributable cases because of Ischemic Heart Disease (IHD) Mortality in Adults having age greater than 25 Years which was attributed effects of long term contact to $PM_{2.5}$ exposure were obtained highest for the year 2018 as 6227 with 95% confidence limits, and lowest in 2022 with value 6187. Cases of IHD were 6214, 6204, and 6217 in the years 2019, 2020, and 2021, respectively. From the findings of GDB 2010 Lelieveld et al. (2015) estimated that there were 305266 of mortality attributable to IHD in entire India. When calculated on the basis of 5 years average between 2018 to 2022, ENC for mortality due to IHD for adults (25+ years) were 6211 for each year. **Figure 3** depict RR due to $PM_{2.5}$ exposure for above mentioned four cases corresponding to complete five-year average from 2018 to 2022 in North-West Delhi. Thus, in this study, health risks associated with exposure to $PM_{2.5}$ were quite high for North-West Delhi and need to be addressed.

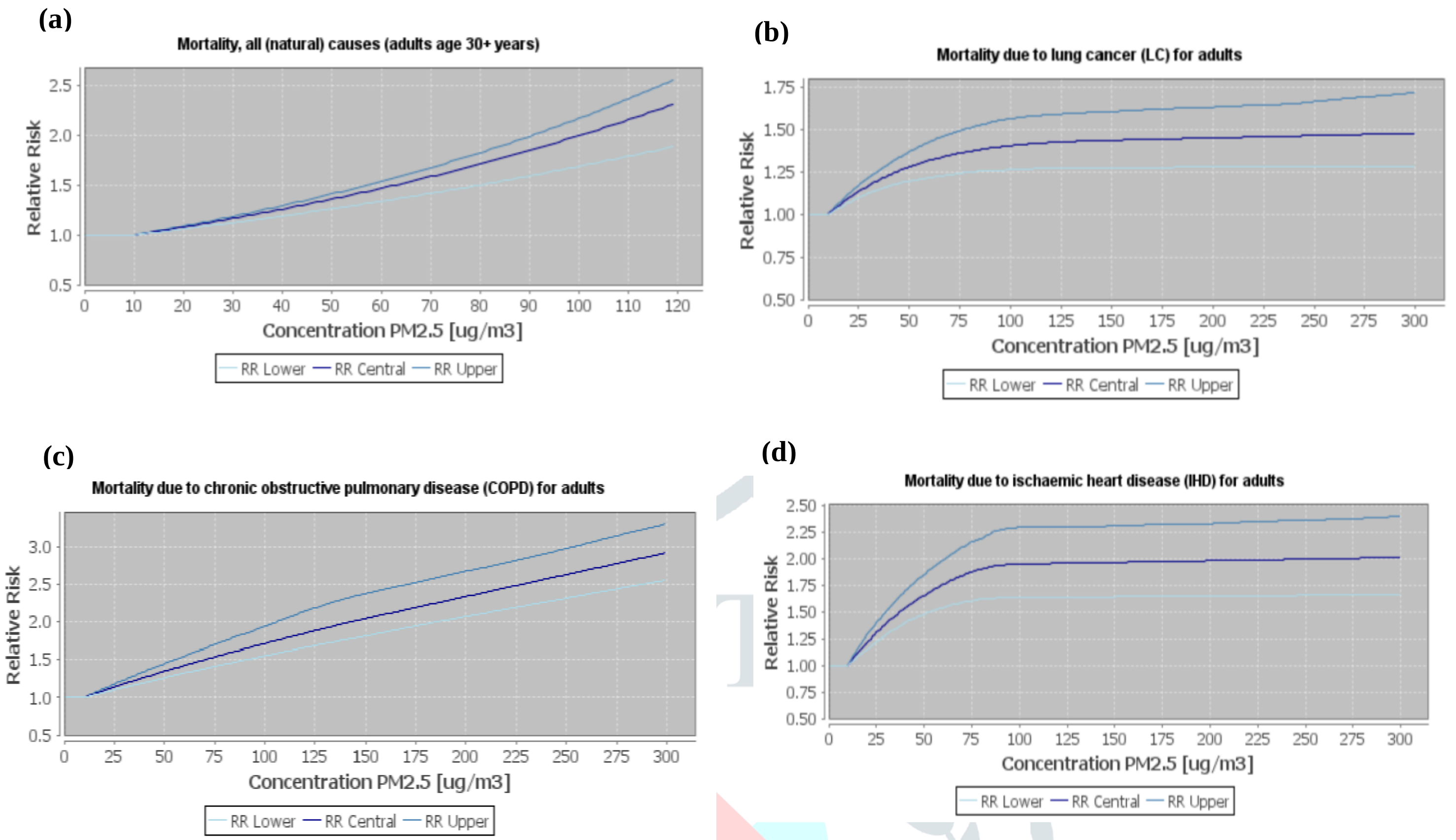

Fig.3. Graph showing relative risk for mortality due to (a) ANCs (adults having age above 30 years), (b) LC for adults, (c) COPD for adults, (d) IHD for adults

IV. Conclusions:

This study was conducted in North-West Delhi to examine the impact on health related to $PM_{2.5}$ by using AirQ+ tool. This study focused on four specific cases i.e., Mortality, ANCs (adults age 30+ years), due to LC for adults, due to COPD for adults (above 30 year), due to IHD for adults (above 25 years). The primary findings are as given:

1. From the annual variation plot, we have obtained maximum value of $PM_{2.5}$ in the year 2018 as 128.7 µg/m^3 and minimum value was obtained for the year 2022 as 96.1 µg/m^3.
2. From analysis of health impact due to exposure to $PM_{2.5}$, we found highest number of attributable cases in 2018, and lowest in 2022. In year 2018, attributable cases of mortality due to ANCs were 17747, due to LC were 1160, due to COPD were 1405 and due to IHD were 6227. In the year 2022, attributable cases of mortality due to ANCs were 14357, due to LC were 1104, due to COPD were 1202 and due to IHD were 6187.
3. When calculated by taking five years average, attributable cases of mortality due to ANCs were 16272, due to LC were 1141, due to COPD were 1318 and due to IHD were 6211 annually.

These findings suggest that in North-West Delhi, exposure to $PM_{2.5}$ had a noteworthy impact on public health, leading to a significant number of cases of mortality. It is important to reduce $PM_{2.5}$ levels in air so as to ultimately reduce the adverse effects on public health. AirQ+ can be utilized in understanding the specific health outcomes associated with air pollution exposure and the extent of their impact and with the help of this policymakers and public health authorities can develop targeted interventions to reduce air pollution levels and protect the well-being of the population.

V. Acknowledgement:

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