PUBLIC HEALTH IMPACT OF AIR POLLUTION IN RANGPUR: ESTIMATING COPD ATTRIBUTABLE TO $PM_{2.5}$, PM_{10}, AND O_3 BY THE AIRQ MODEL

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ABSTRACT

Chronic obstructive pulmonary disease (COPD) is a serious and growing public-health issue worldwide, and the burden becomes even heavier due to poor air quality. This study aims to investigate COPD in Rangpur district by air pollution, which was carried out an assessing using the World Health Organization's (WHO) recommended approach. The analysis was performed with the AirQ2.2.3 software developed by the WHO European Centre for Environment and Health. For this assessment, the daily average concentrations of $PM_{2.5}$ and PM_{10}, along with 1-hour average concentrations of ozone (O_3) data extracted by Google Earth Engine, are used to estimate exposure levels based on the population and the resulting health effects. The primary outcome of interest was the fraction of hospital admissions related to COPD (HA-COPD) that is linked to these pollutants. This research analysis suggests that approximately 2% (95% CI: 0.8–3.1%) of COPD-related hospital admissions in Rangpur are linked to O_3. Also, this study highlighted that $PM_{2.5}$, PM_{10}, and O_3 contribute meaningfully to the burden of COPD in Rangpur. The results emphasize the need for stronger air-quality management and targeted policy actions to reduce pollution-related respiratory illnesses. To suggest that further detailed studies would also help refine these estimates and support more effective public-health planning.

Keywords: *Air Pollution, Chronic Obstructive Pulmonary Disease (COPD), Respiratory Health, AirQ2.2.3, Public Health.*

1. INTRODUCTION

Exposure to air pollution can lead to both short-term (acute) and long-term (chronic) health effects. Severe pollution events in Europe and the United States during the 20th century demonstrated that high concentrations of pollutants could cause widespread illness and deaths, highlighting the strong link between air quality and human health (Pascal et al., 2013; Schnell et al., 2015; Wang et al., 2015). Chronic obstructive pulmonary disease (COPD) is a major global health concern, affecting populations in both highly and lower developed countries (Schikowski et al., 2010). Particulate matter ($PM_{2.5}$ and PM_{10}) and ozone (O_3) are particularly concerning in urban environments because they are closely linked to traffic, industrial emissions, and other human activities (Ferrante et al., 2012; Goldizen et al., 2015).

The concentrations of these pollutants are influenced by both emissions and local climate conditions (Hassan et al., 2015). Several studies have shown strong associations between particulate pollution and adverse respiratory outcomes, including COPD, especially among vulnerable groups such as children and the elderly (Bravo et al., 2015; Thurston & Ito, 1999). Different health issues occur due to higher quantities of O_3, $PM_{2.5}$, and PM_{10} have induced oxidative stress, airway inflammation, reduced lung function, and exacerbation of respiratory diseases (Antus & Kardos, 2015; Patel et al., 2013; Gilmour et al., 2003). Even moderate increases in ozone levels have been associated with higher rates of hospital visits for asthma and COPD, with children being particularly affected (Stieb et al., 2009; Sacks et al., 2014).

In Bangladesh, air pollution is not limited to minor places; big cities like Dhaka and Chattogram deal with even more complicated and serious issues. Large amounts of dust are produced in Dhaka by uncontrolled construction and rapid urbanization, which considerably raises PM2.5 concentrations during the dry months (World Bank, 2018). Clusters of coal-fired brick kilns around the city and significantly contribute to particle pollution throughout the winter. High amounts of NO_x, SO_2, and black carbon are released into densely populated districts by outdated and badly maintained diesel automobiles, making traffic emissions a serious problem as well (Rahman et al., 2019). Heavy industrial activity, such as steel mills, cement factories, chemical facilities, and shipbreaking, further compromises Chattogram's air quality (Alam & Hossain, 2019). Open waste burning and seasonal transboundary pollution from nearby regions further intensify pollution levels across both cities (Gurjar et al., 2016). These combined factors illustrate how Dhaka and Chattogram represent the broader national struggle with air pollution driven by rapid development, weak regulatory enforcement, and expanding industrialization.

Rangpur, a rapidly growing district in northern Bangladesh, faces challenges with urban air pollution due to population growth, increased traffic, and industrial activity. Assessing the impact of air pollution on COPD in this region is therefore essential. Tools such as AirQ2.2.3, developed by the WHO European Centre for Environment and Health, allow researchers to estimate health impacts of air pollutants and evaluate scenarios based on changes in emissions (WHO, 2004; Colls, 2006).

This study focused on $PM_{2.5}$, PM_{10}, and O_3 concentrations in Rangpur to assess their contribution to hospital admissions for COPD (HA-COPD). The objectives were: i. To estimate the proportion of COPD hospital admissions attributable to $PM_{2.5}$, PM_{10}, and O_3 using AirQ2.2.3. ii. To analyze trends in these pollutants and associated COPD cases over the study period. iii. To provide evidence to inform local policy and public health interventions aimed at improving air quality and reducing the burden of respiratory diseases in Rangpur.

COPD is characterized by chronic airflow limitation, with symptoms such as persistent cough, shortness of breath, and sputum production (Vestbo, 2014; Vestbo & Wedzicha, 2013). Globally, it is projected to become one of the leading causes of death and disability in the coming decades (Murray & Lopez, 1997; Chapman et al., 2006). Recognizing air pollution as a significant trigger for COPD underscores the need for effective air quality management, especially in rapidly urbanizing cities like Rangpur.

2. MATERIALS AND METHODS

2.1 Study Area

Rangpur is a major district in northern Bangladesh, located approximately at a latitude of 25°44′N and longitude 89°15′E as shown in Figure 1, with an average elevation of around 34 meters above sea level. It is one of the fastest-growing urban areas in the Rangpur division of Bangladesh, with a population of approximately 3.2 million people, according to the latest census. The district has multiple communities, such as residential, commercial, and industrial zones, with increasing vehicular traffic, brick kilns, and small-scale industries contributing to urban air pollution. Due to these factors, particulate matter ($PM_{2.5}$ and PM_{10}) and ozone (O_3) concentrations have become a growing public health concern.

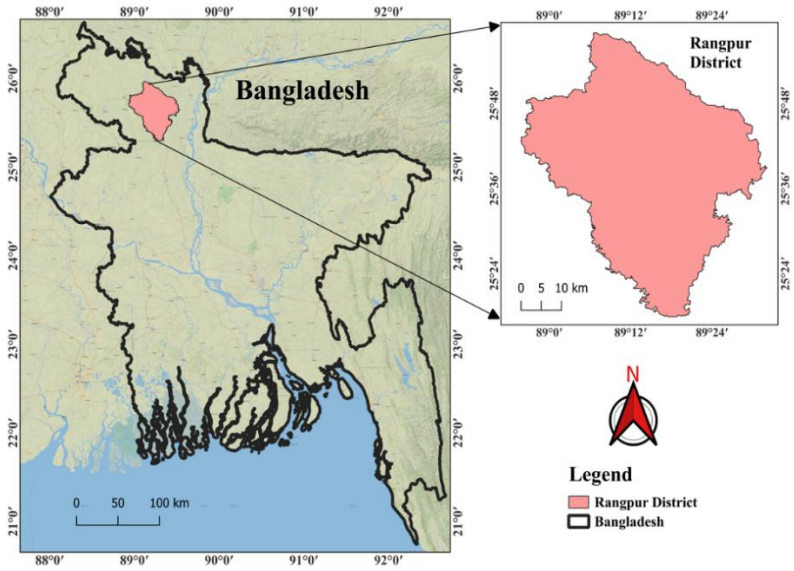


Figure 1: Study Area

2.2 Study Framework

This study integrates satellite-based air-quality monitoring, exposure assessment, and health impact to quantify COPD attributable to $PM_{2.5}$, PM_{10}, and O_3 in Rangpur, as shown in Figure 2. Air-pollution concentrations for 2020–2023 are retrieved and processed using Google Earth Engine (GEE) satellite datasets, providing spatially continuous estimates of particulate and ozone levels.

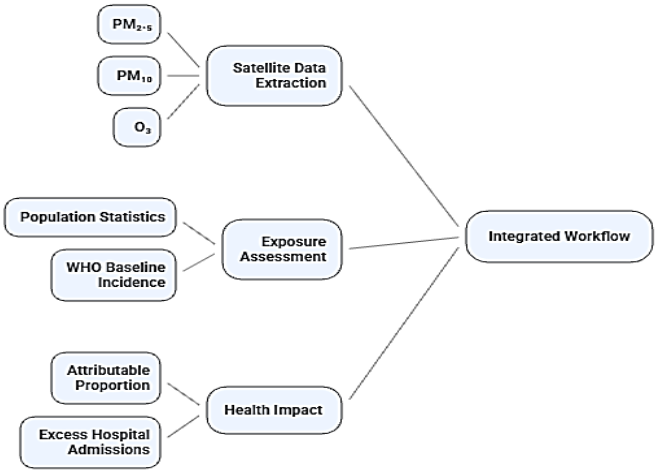


Figure 2: Framework of this Study

These pollutant datasets, combined with Rangpur's population statistics and WHO baseline COPD incidence values, are used to define exposure conditions. Using WHO's AirQ2.2.3 model, the framework applies GBD 2020 concentration–response functions to calculate the Attributable Proportion (AP) of COPD hospital admissions linked to each pollutant and to estimate the Excess COPD-related Hospital Admissions resulting from current exposure levels. This integrated workflow, spanning satellite data extraction, seasonal pollutant trend analysis, exposure–response modelling, and health-risk quantification, provides evidence essential for understanding the pollution-driven COPD burden and guiding effective air-quality and public-health interventions.

2.3 AirQ Software

To quantify the proportion of COPD hospital admissions attributable to $PM_{2.5}$, PM_{10}, and O_3, the AirQ2.2.3 software was employed. This tool estimates health impacts based on established concentration-response functions, population exposure, and baseline incidence rates. The analysis provided estimates of excess hospitalizations due to each pollutant, allowing identification of the most significant contributors to respiratory morbidity. Temporal trends in pollutant concentrations and associated COPD cases were analyzed using descriptive statistics and graphical representations. Seasonal variations were examined to identify high-risk periods, particularly during winter months when particulate matter levels peaked. Year-on-year comparisons helped evaluate improvements or deteriorations in air quality over the study period. For conducting this study, the World Health Organization (WHO) approach using AirQ2.2.3 software, developed by the WHO European Centre for Environment and Health (Colls, 2006; WHO, 2004). The software allows for estimating the health impacts of exposure to specific air pollutants on a defined population over a period of one year. The main health outcome assessed in this study was COPD-related hospital admissions (HA-COPD). The software calculates the attributable proportion (AP) of health outcomes, defined as the fraction of cases in a population that can be attributed to exposure to a given pollutant. Baseline incidence values were adopted from WHO defaults (101.4 per 100,000 population per year) due to the unavailability of local COPD incidence data, as recommended in previous studies (Fattore et al., 2011; Gholampour et al., 2014). In this study, the AirQ+ software developed by the World Health Organization (WHO) was used to estimate the potential health impacts of ambient PM2.5 exposure on COPD outcomes in Rangpur. The methodology involved several steps. First, annual and seasonal mean concentrations of PM2.5 for Rangpur were compiled from validated monitoring sources and cross-checked with national datasets to ensure representativeness for population-level exposure assessment. These concentration values were entered into the AirQ+ interface along with Rangpur's population size, baseline mortality rates, and disease-specific incidence estimates. AirQ+ applies concentration–response functions (CRFs) derived from epidemiological studies, primarily those recommended by WHO, to estimate the attributable proportion (AP) and attributable cases (AC) of COPD related to PM2.5 exposure. The software calculates the relative risk (RR) based on established CRFs and combines it with local exposure data to quantify the number of COPD cases or deaths that can be attributed to pollution. For uncertainty analysis, AirQ+ provides lower and upper confidence intervals using predefined CRF ranges, allowing more robust interpretation. This standardized methodological framework ensures comparability with global burden-of-disease assessments and has been widely used in similar air-pollution studies across South Asia (Khaniabadi et al., 2017). As no previous study has applied AirQ+ specifically to Rangpur's COPD burden, the present analysis fills an important methodological and geographic gap by integrating local exposure data with internationally validated health-risk models.

3. RESULTS

3.1 Pollutants of Air

The comprehensive results for the pollutants of $PM_{2.5}$, PM_{10}, and O_3 concentrations in Rangpur from 2020 to 2023 in Figure 3a–3c illustrate the monthly and inter-annual variability. The heatmap in Figure 3a shows the monthly variation in $PM_{2.5}$ concentrations in Rangpur from 2020 to 2023. Overall, a clear seasonal pattern is observed, with higher levels of $PM_{2.5}$ during the winter months (December to February) and

lower levels in the monsoon and post-monsoon months (June to October) due to lower relative humidity and temperature (Majumder et al., 2025). The highest concentrations occur in December-February, with values often exceeding 60 µg/m³, reflecting the combined influence of low temperatures, temperature inversions, shallow boundary layers, and intensified biomass burning and combustion activities. A steady reduction is observed during March–May, marking the transition into warmer conditions. The lowest PM2.5 levels appear during June–September, coinciding with monsoon rainfall, which effectively removes fine particulate matter through wet deposition. Concentrations begin to rise again in October, completing the annual pollution cycle. Inter-annual variations are noticeable but moderate; for instance, the winter peak in 2023 is slightly higher than in earlier years, suggesting the influence of changing emissions or meteorological factors.

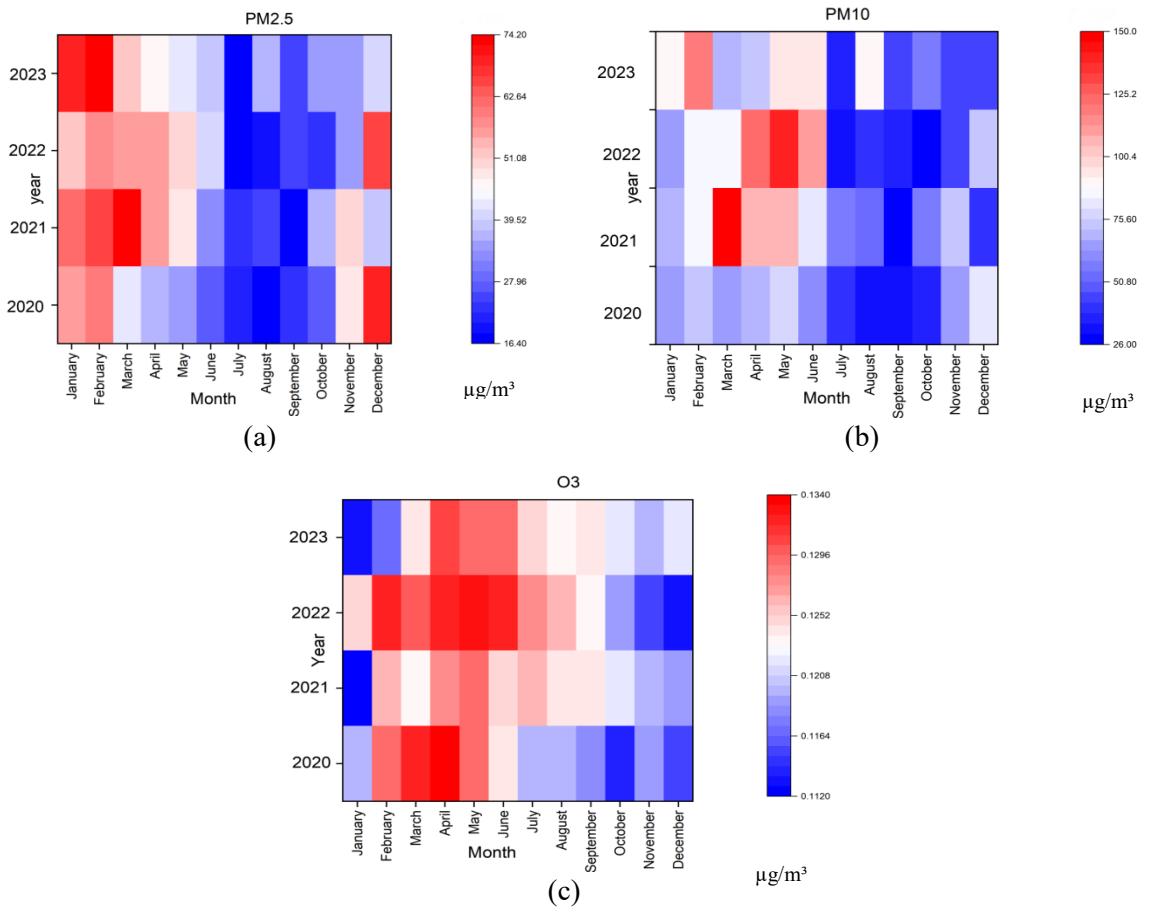


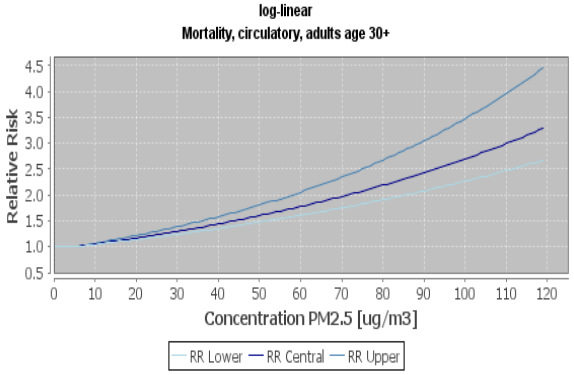
Figure 3. Heatmap of (a) $PM_{2.5}$; (b) PM_{10}; (c) O_3, from 2020 to 2023

However, the monsoon minima remain largely consistent across all years. A similar seasonal signature is observed in PM10 (Fig. 3b). The highest levels are recorded in January and December, regularly surpassing 125 µg/m³, indicating substantial accumulation of coarse particles during winter. These elevated values are likely linked to dry atmospheric conditions, reduced wind speed, and intensified resuspension of dust from roads and open surfaces. PM10 concentrations decline steadily from February to June, followed by the cleanest air period during July-August, when monsoon rainfall dominates deposition processes. A gradual increase resumes from September onward. Inter-annual differences are subtle: winter peaks in 2023 appear marginally lower than those in 2021-2022, indicating slight improvements but still within the typical seasonal range. The O_3 concentrations (Fig. 3c) show a different pattern compared to particulate pollutants. The highest values occur in January (0.1340), followed by a consistent, nearly linear decline until June (0.1120). This reduction likely reflects decreasing photochemical activity and changes in precursor emissions. Although data for July-December are unavailable, the first-half trend suggests strong seasonality in ozone chemistry driven by temperature, solar intensity, and atmospheric oxidation processes. Overall, the findings indicate a winter

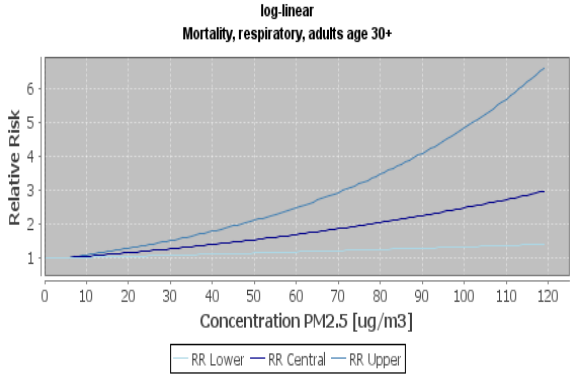
deterioration and monsoon improvement in air quality for Rangpur. Seasonal meteorology remains the dominant driving factor, emphasizing the need for targeted emission control during the winter months when pollution buildup is most severe.

3.2 Exposure-Response Function

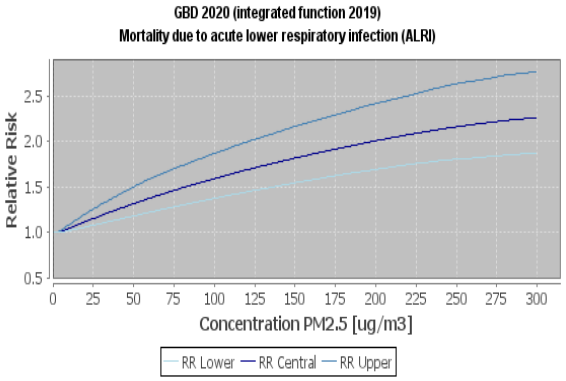
These charts, sourced from the Global Burden of Disease (GBD) 2020 study and other log-linear models, quantify the increased risk of death from specific diseases as exposure to particulate matter (PM2.5 and PM10) rises. A consistent and critical finding across all charts is that there is no safe threshold; the risk of mortality begins to increase from very low concentrations. The relationship is generally non-linear, with the Relative Risk (RR) rising steeply at lower concentrations and flattening out at higher concentrations, though it continues to increase.



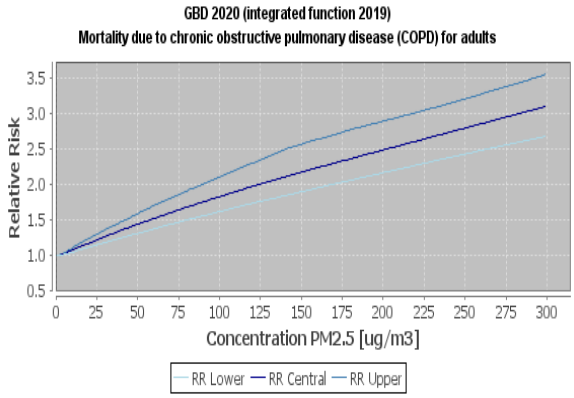
a) PM2.5 and Circulatory Mortality in Adults (30+)



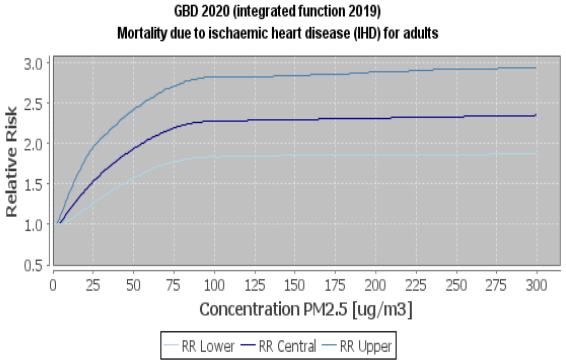
b) PM2.5 and Respiratory Mortality in Adults (30+)



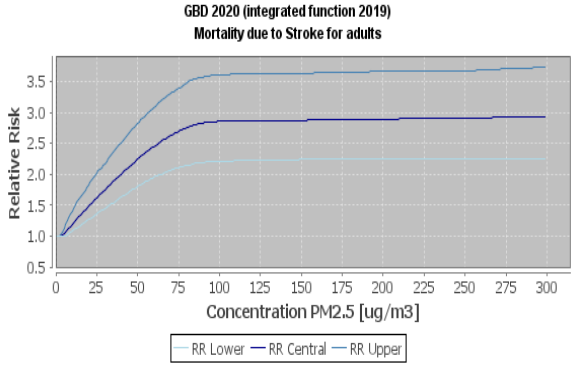
c) PM2.5 and Acute Lower Respiratory Infection (ALRI) Mortality (GBD 2020)



d) PM2.5 and COPD Mortality (GBD 2020)



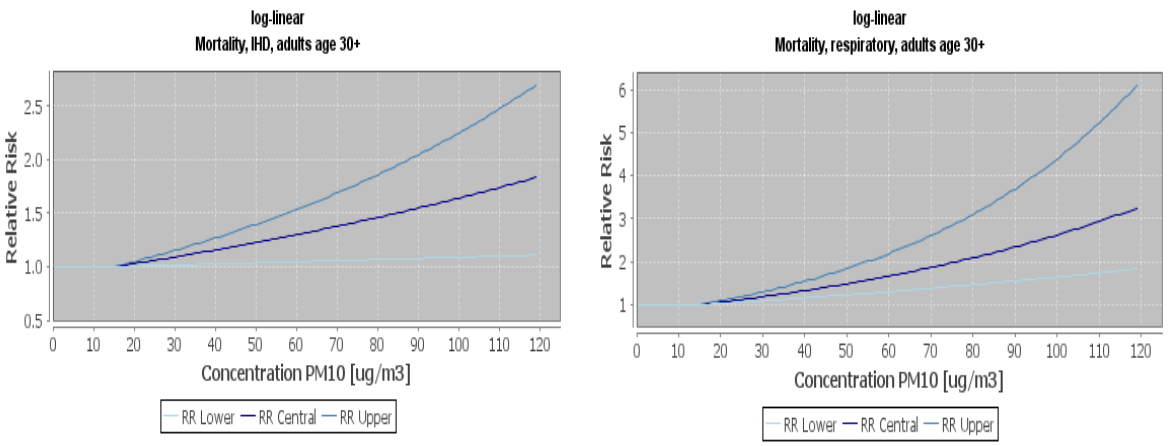
e) PM2.5 and Ischemic Heart Disease (IHD) Mortality (GBD 2020)



f) PM2.5 and Stroke Mortality (GBD 2020)

Figure 4. Mortality due to PM2.5 pollutants

Figure 4(a) shows the risk of death from circulatory diseases (like heart attacks and strokes). The Relative Risk starts just above 1.0 at 0 µg/m³ and increases sharply, reaching approximately 1.5 at 45 µg/m³. This indicates a 50% increased risk of dying from a circulatory disease at that exposure level compared to a theoretical baseline with no PM2.5. 4(b) displays the risk for respiratory mortality. The curve is even steeper than for circulatory diseases. The RR reaches about 1.5 at a lower concentration of around 35 µg/m³, suggesting that respiratory mortality is more sensitive to PM2.5 exposure in this model, with risks increasing more rapidly at lower levels. 4(c) tracks the risk of dying from infections like pneumonia. It shows a very steep initial increase, with the RR climbing to nearly 2.0 by 50 µg/m³. This implies that the risk of dying from an ALRI doubles at this exposure level, highlighting the acute vulnerability of the respiratory system to particulate pollution. 4(d) shows Chronic Obstructive Pulmonary Disease - COPD. For this chronic lung disease, the risk curve is also strong. The RR rises to about 1.8 at 50 µg/m³ and continues to climb to nearly 2.5 at 100 µg/m³. This demonstrates that long-term exposure to PM2.5 significantly accelerates the progression and fatality of chronic respiratory conditions. 4(e) shows the risk of death from heart disease caused by narrowed heart arteries. The RR increases to about 1.4 at 50 µg/m³ and nearly 1.7 at 100 µg/m³. This confirms that PM2.5 is a major environmental risk factor for fatal heart attacks, likely through mechanisms that promote inflammation and atherosclerosis. 4(f) is the risk of fatal stroke shows a similar, slightly steeper curve than IHD. The RR reaches approximately 1.5 at 50 µg/m³ and over 1.8 at 100 µg/m³. This indicates a substantial and growing burden of cerebrovascular mortality due to air pollution.



a) PM10 and Ischemic Heart Disease (IHD) Mortality in Adults (30+)

b) PM10 and Respiratory Mortality in Adults (30+)

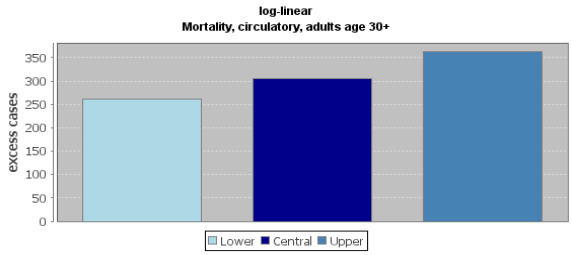
Figure 5. Mortality due to PM10 pollutants

Figure 5(a) models the risk of fatal heart disease from exposure to the larger PM10 particles. The curve is less steep than its PM2.5 counterpart (Chart 3), with an RR of about 1.2 at 50 µg/m³. This suggests that while PM10 contributes to heart disease mortality, PM2.5 is a more potent risk factor per unit of mass. Figure 5(b) shows that the risk of respiratory mortality from PM10 increases, but less dramatically than for PM2.5. The RR reaches about 1.25 at 80 µg/m³. This reinforces that the finer PM2.5 particles, which can penetrate deeper into the lungs and bloodstream, pose a greater health threat.

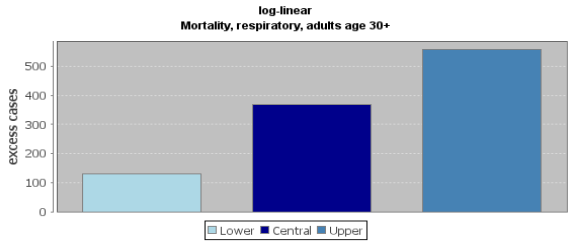
3.3 Attributable Cases

Figure 6 reveals the most devastating impact of air pollution in Rangpur. It's a brutal assault on the human heart. Figure 6(a-g) shows the data for circulatory diseases, and Ischaemic Heart Disease (IHD) shows not just a statistical increase, but hundreds of families each year losing a loved one to a heart attack that would not have occurred in cleaner air. The data reveals a devastating burden on cardiovascular health. For general circulatory mortality, we are seeing an estimated 200 to 300 excess deaths annually among adults. This broad category is sharply focused by the data on Ischaemic Heart Disease (IHD), which alone is responsible for a staggering 1,500 to 2,000 excess deaths each year. This

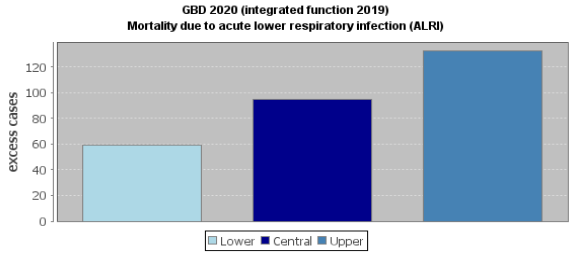
means that the single largest killer attributable to air pollution in Rangpur is heart disease, with the "Central" estimate likely representing nearly 2,000 families losing a loved one prematurely.



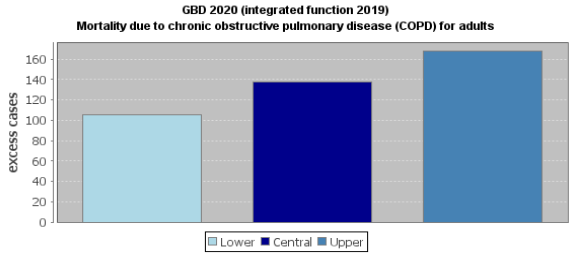
a) Circulatory Mortality in Adults (30+)



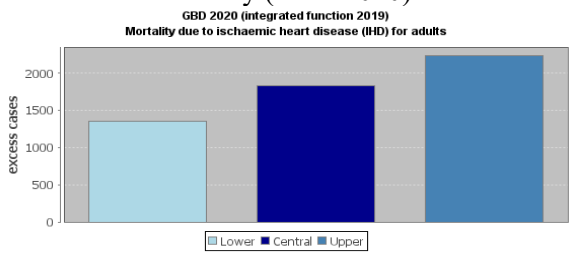
b) Respiratory Mortality in Adults (30+)



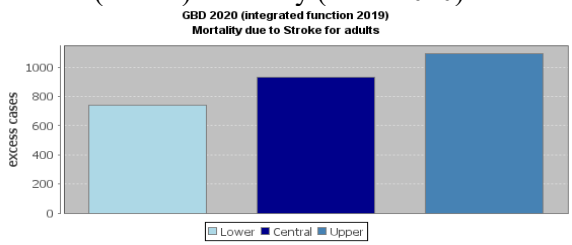
c) Acute Lower Respiratory Infection (ALRI) Mortality (GBD 2020)



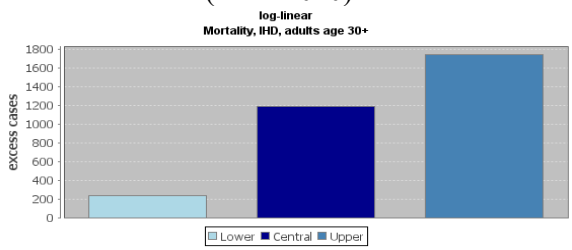
d) Chronic Obstructive Pulmonary Disease (COPD) Mortality (GBD 2020)



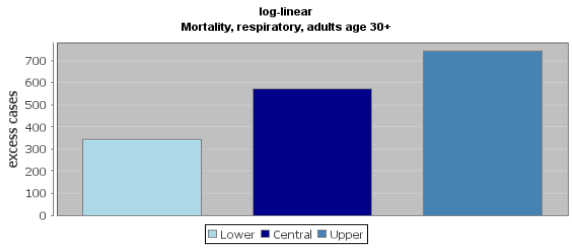
e) Ischaemic Heart Disease (IHD) Mortality (GBD 2020)



f) Stroke Mortality (GBD 2020)



g) Ischemic Heart Disease (IHD) Mortality in Adults (30+)



h) Respiratory Mortality in Adults (30+)

Figure 6. Attributable Cases

Figure 6(b,h) shows the direct consequence of the district gasping for air. For those with vulnerable lungs, the elderly, the lifelong resident, and the person with asthma, every day of high pollution is a fight. This chart translates that daily struggle into its most tragic outcome. Each "excess case" represents a member of our community for whom breathing, the most fundamental act of life, became an insurmountable challenge. Figure 6(c) is perhaps the most poignant, as it likely reflects the impact on the very young and the very old. When we see dozens of excess deaths from infections like pneumonia, it means that a child's common cold or an elder's bout of bronchitis is being tragically transformed into a fatal illness by the polluted air. Their developing or weakened immune systems are no match for the added assault of constant pollution. an estimated 80 to 100 excess deaths per year from severe respiratory infections like pneumonia. This figure is critical because it often represents the most vulnerable in the population, the very young and the very old, whose lives are cut short. After all, air pollution weakens their ability to fight off a common infection. Figure 6(d) is the story of a long, slow

goodbye. COPD is a debilitating disease that robs people of their breath, turning simple walks or even household chores into monumental tasks. For Chronic Obstructive Pulmonary Disease (COPD), the data show a heavy and specific toll, with approximately 100 to 140 excess deaths annually. Each one of these cases represents a long and difficult journey of chronic illness, where the quality of life is severely diminished by breathlessness, all culminating in a death that was accelerated by the constant inhalation of polluted air. Figure 6(e) shows how air pollution doesn't just attack the heart but also strikes the brain. The hundreds of excess stroke deaths indicate a wave of sudden, catastrophic events that leave families shattered. A stroke can instantly change everything, robbing a person of their mobility, their speech, their independence, or their life. The impact on cerebrovascular health is alarming. The data indicates that strokes, caused by air pollution, are claiming between 600 to 800 lives every year in Rangpur. This places stroke as the second-largest cause of pollution-related mortality after heart disease, representing a massive wave of sudden, devastating health events that tear through the community. Cases attributable were identified for ozone (O3) because the measured concentrations in the study area remained below the threshold levels required for AirQ health-impact estimation. As a result, the software could not generate any O3-related COPD burden or associated risk values. This indicates that, unlike PM2.5, ozone layers did not contribute significantly to respiratory health impacts in Rangpur during the study period.

AI Declaration

The author declares the use of ChatGPT solely for improving language clarity and correcting grammatical issues. No AI tools were used in the research methodology, data analysis, result interpretation, or manuscript development beyond linguistic assistance.

4. CONCLUSIONS

This study estimated the proportion of COPD hospital admissions attributable to $PM_{2.5}$, PM_{10}, and O_3 in Rangpur using AirQ2.2.3. The analysis revealed that both $PM_{2.5}$ and PM_{10} consistently exceeded international safety limits, contributing substantially to the burden of COPD in the population, while O_3 also played a notable role in hospitalizations. Trend analysis over the study period showed seasonal peaks in particulate pollution during winter, with a modest improvement in pollutant levels from 2022 to 2023, suggesting that air quality interventions can have measurable effects. Despite these improvements, pollutant concentrations remain high enough to pose significant risks for premature mortality from respiratory and cardiovascular diseases. The findings underscore the strong link between short-term exposure to these pollutants and increased COPD admissions, highlighting the urgent need for targeted mitigation strategies. The study also demonstrates that even small reductions in $PM_{2.5}$, PM_{10}, and O_3 can translate into meaningful health benefits for Rangpur's residents. Evidence from the observed trends provides a clear rationale for local policymakers to prioritize air quality management, particularly during the high-risk winter months. Public awareness and behavioral changes, alongside regulatory actions, emerge as key components for reducing the health burden. Ultimately, this study not only quantifies the health impact of air pollution in Rangpur but also provides actionable insights to guide effective public health interventions.

Therefore, we echo the recommendations from the Tabriz study and tailor them to Rangpur's context:

i. Implement Targeted Source Control: Urgently enact policies to address the root causes, particularly during the high-pollution winter season. This must include traffic management, restrictions on fossil fuel use, promotion of eco-friendly public transport, and regulation of industrial and construction emissions.
ii. Formalize Health Impact Quantification: Adopt the methodology used in this analysis to establish a permanent health impact surveillance system. By using the concentration-response functions, authorities can continuously quantify the disease burden (e.g., number of attributable deaths and hospitalizations) to monitor progress and justify public health spending.
iii. Commit to Ongoing Research and Monitoring: As recommended for Iran, there is a "high need for further studies" in Rangpur. Geographic, demographic, and seasonal variations must be better understood through sustained local epidemiological research and expanded air quality monitoring.

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