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Evaluation of the Health Impacts of $PM_{2.5}$ (Stroke, IHD, LRI)

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***Abstract:** In this study, an attempt has been made to determine the human health risk due to exposure to $PM_{2.5}$ in the State of Uttar Pradesh during the years 2017, 2018, and 2019. The values of Burden of Disease for the respective years and location were taken from the Global Burden of Disease (GBD) Portal. The Relative Risk is calculated using the AIRQ+ software from which Population Attributable Fraction was estimated. We got the Mortality by using the values of Attributable Burden of Disease. From which we came the results that the values of relative risk (central) for Stroke for the years 2017, 2018, and 2019 are 1.436, 1.429, and 1.388 respectively, and the relative risk for Ischemic Heart Disease (IHD) is 1.522, 1.528, and 1.646 for the year 2017, 2018 and 2019 respectively and the values for relative risk for LRI for the year 2017, 2018, and 2019 is 1.825, 1.815 and 1.701 respectively.*

***Keywords:** Air Pollution, $PM_{2.5}$, Stroke, Ischemic Heart Disease (IHD), LRI, Global Burden of Disease (GBD) Portal, Relative Risk, Attributable Burden of Disease, Mortality.*

I. INTRODUCTION

Air pollution is one of the most challenging environmental problems, which must be faced on a local, regional and global scale. Industrial activities, including energy production, road traffic, and household combustion, have been identified as important emission sources of a wide range of pollutants (EEA, 2018; Prüss-Ustün et al., 2016). It is well known that air pollution is associated with adverse health effects such as respiratory and cardiovascular diseases, cancer, and even death. According to the World Health Organization (WHO), in 2012, 3.0 million deaths were attributable to outdoor air pollution, while around 6.5 million deaths (11.6% of all world deaths) would attributable to indoor and outdoor air pollution if they were taken into account together (WHO, 2016a). In a recent study (Stanaway et al., 2018), the attributable number of deaths to air pollution in indoor and outdoor environments was set at 4.9 million in 2017.

Exposure to ambient fine particulate matter ($PM_{2.5}$) is one of the leading causes of health burden in India. The rising ambient $PM_{2.5}$ concentration and its staggering health burden led the Government of India to launch the National Clean Air Program (NCAP) in early 2018. Though the NCAP addressed air pollution as a national-scale problem, its focus on the urban centres essentially fails to recognize the air quality status in the rural areas. This is reflected in the ground-based monitoring network maintained by the Central Pollution Control Board (CPCB) with all of the 230+ continuous and 650+ manual monitoring sites (www.cpcb.nic.in) deployed in the urban centres. Although the number of ground-based monitoring sites seems to be large, it is not adequate for air quality management because (1) the network is disproportionately distributed $PM_{2.5}$ monitoring started in 2009 (unlike PM_{10} which has a longer record), but the network expanded nationally only after 2015–2016; and (3) the manual monitoring sites only sample twice a week and do not provide continuous data. The population-weighted distance to the nearest monitoring site in India is estimated to be 80 km. On average, seven million people die across the world from air pollution-related causes annually. According to the World Air Quality Report released last year, India is ranked five among the world's most polluted countries. Not only this, 21 of the 30 most polluted cities in the world are in India.

In India, large amounts of gaseous and particulate pollutants regularly emitted by industries, thermal power plants, and vehicles (both heavy-duty diesel vehicles such as trucks and gasoline fuelled cars) cause great health risks. Upadhyay revealed that the health impact of air pollutants is extremely significant in polluted urban regions of India. Delhi, the national capital is already ranked high (11th globally) among the most polluted cities in the world in terms of particulate matter concentrations. Amongst the world's twenty most polluted cities with high aerosol concentrations, four of these are located in Uttar Pradesh namely Allahabad, Firozabad, Lucknow, and Kanpur. Lucknow, the capital of Uttar Pradesh is currently ranked 18th globally.

In epidemiology "risk" is defined as a measure of the statistical likelihood of having the severity of adverse events (e.g. illness or death) due to exposure to some factor (e.g. toxic chemical) (Lowrance, 1976).

The health risk is the probability or chance that exposure to a hazardous substance, which make human sick and it is equal to the multiplication of hazard and exposure. The human health risk (HHR)assessment involves four major steps as follows (NRC, 1983): (1) Hazard identification – elements with known toxicity (like PM_{10}, SO_2, NO_2 are responsible for different health effects like cardiovascular mortality, respiratory mortality, COPD, etc.). The knowledge about how hazardous a substance (pollutants) is, comes from animal experiments or long-time human studies. (2) Exposure assessment involves the estimation of the number of hazardous pollutants inhaled by a certain population. Exposure information comes in two ways: (a) monitors substance concentration at different places in the human community, or (b) from dispersion models that account for exposure based on the released amount of hazardous substance from a different source. (3) Concentration-response assessment: it reflects the probability of health effects based on the dose of inhaled air pollutants. Finally, (4) HHR assessment is calculated by a mathematical model based on the exposure and dose-response assessments.

To support the decisions of policymakers, it is necessary to quantify the effects of air pollution and the potential changes due to mitigation policies' implementation. To measure health outcomes due to air pollution exposure, WHO developed the AIRQ+ model. This model has been applied internationally in Europe, but also worldwide (Al-Hemoud et al., 2018). AIRQ+ measures the contribution of air pollution to mortality/ morbidity using the population attributable fraction (PAF). PAF is the proportional reduction in population morbidity or mortality, which would occur if exposure to air pollution was reduced to an alternative exposure scenario (WHO, 2016b), e.g.WHO air quality threshold limits (annual mean limits 10 and 20 µg/m3 for $PM_{2.5}$ and PM_{10}, respectively (WHO, 2006)). As a complementary tool, the environmental burden of disease using disability-adjusted life years (DALYs) can assess the health impact (mortality and morbidity) that may be attributed to environmental factors such as air pollution (Prüss-Ustün et al., 2016). The DALYs, as a way to compare overall health and life expectancy of different populations, take into account the years of life lost due to premature death (YLL), as well as the years of healthy life lost due to a disease (YLD) (Devleesschauwer et al., 2014).

A. *Comparison of $PM_{2.5}$ and PM_{10}*

$PM_{2.5}$	Contains fine particles, secondary aerosols, combustion particles, re-condensed organic metallic vapor, and acid components. Can reach all the way down to the alveoli in the lungs.	Can be inhaled through respiration by the human body; Cross into the arteries, hardening them; exposure results in coronary heart ailments.
PM_{10}	The dust from roads and industries, as well as particles formed during combustion.	Depending on their size, coarse particles can lodge in the trachea (upper throat) or in the bronchi and typically contribute to allergic reactions and respiratory diseases, as well as impact general wellbeing

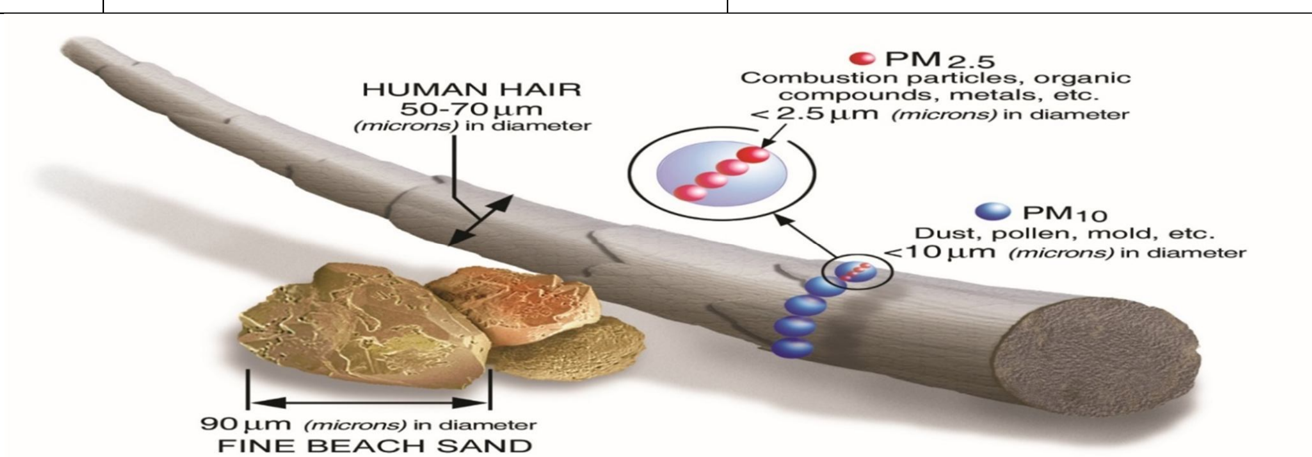

Figure 1 Comparison of PM2.5 and PM10

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B. Health Effects Of $Pm_{2.5}$

New diseases and conditions are continually being associated with exposure to air pollution (Grandjean and Landrigan 2006, Landrigan *et al* 2017). Figure 10 shows the diseases and conditions plausibly affected by air pollution, where the ones in bold type are currently included in GBD categories (Thurston *et al* 2017). The GBD estimates the health impacts of PM2.5 exposure for four non-communicable diseases (IHD, CEV, COPD, and LC) and one communicable disease (LRI). IHD is associated with a reduction of blood supply to the heart, potentially leading to a heart attack (Global Burden of Disease Collaborative Network 2017, World Health Organization 2018c, Thurston *et al* 2016). CEV is a group of brain dysfunctions related to disease of the blood vessels supplying the brain, including stroke (Global Burden of Disease Collaborative Network 2017, World Health Organization 2018c). COPD is the incompletely reversible obstruction of the airways, defined by three main characteristics; small airways obstruction (thickening cell walls), emphysema (inflammation), and chronic bronchitis (cough and phlegm) (Global Burden of Disease Collaborative Network 2017, World Health Organization 2018c, Postma *et al* 2015). LC is the abnormal change of cells in the lung, categorized as primary or secondary, and non-small cell or small cell (Global Burden of Disease Collaborative Network 2017, World Health Organization 2018c). LRI is a broad group of infections in the airways and lungs, such as pneumonia (Global Burden of Disease Collaborative Network 2017, World Health Organization 2018).

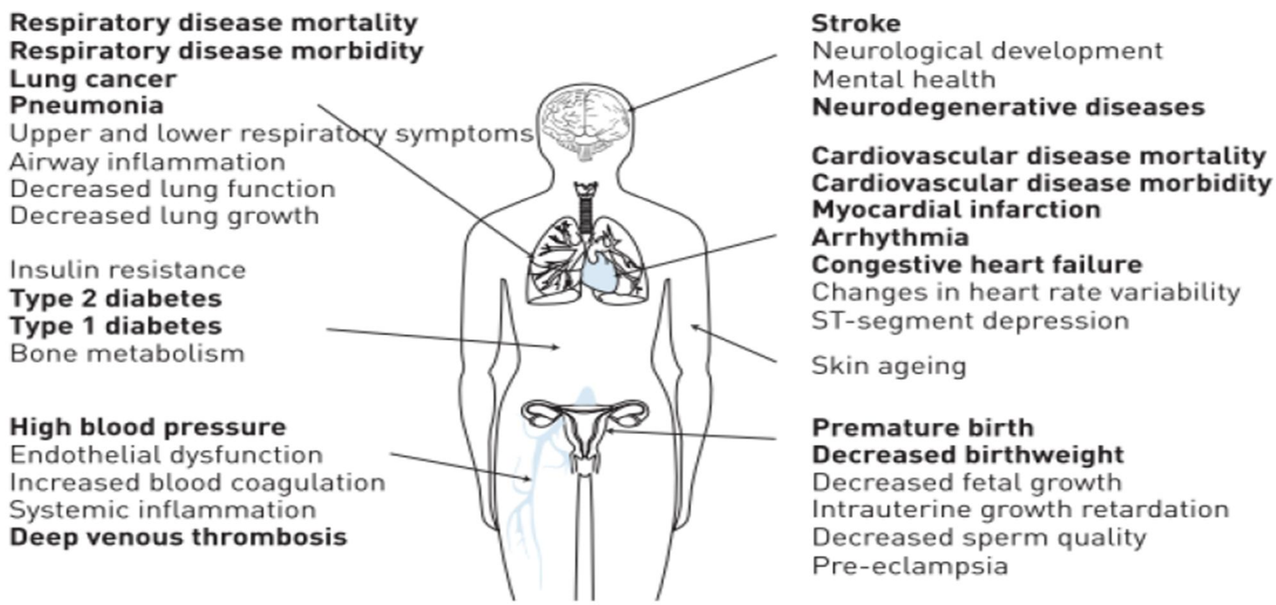


Figure 2: Overview of diseases, conditions, and biomarkers affected by ambient air pollution (Thurston et al 2017).

C. Objectives Of The Research

1) Calculation of Relative Risk for Stroke, IHD, and LRI.
2) Calculation of Population Attributable Fraction (PAF) for the disease.
3) Calculation of Attributable Burden (AB) due to Stroke, IHD, and LRI.

II. LITERATURE REVIEW

This chapter aims to review the various research and studies which were based on the health impact assessment of air pollution.

Alexandra Karambelas and Tracey Holloway et.al. conducted research on Urban versus rural health impacts attributable to $PM_{2.5}$ and O_3 in northern India using the CMAQ model. The outcome was 463 200 (95% CI: 444 600–482 600) premature deaths occurred annually in 2017 as a result of excess $PM_{2.5}$.

Mohsen Ansari and Mohammad Hassan Ehrampoush et.al. 2018 studies on Meteorological correlates and AirQ+ health risk assessment of ambient fine particulate matter in Tehran, Iran and concluded that 6710 (RR= 1.062) deaths may be attributed to long-term exposure to $PM_{2.5}$ concentrations above 10 μg/m3 during March 2017- 2018. 128 deaths per 100000 people in Tehran are related to long-term exposure to $PM_{2.5}$ in the study period, while this value is 2.41 times more than the world average number of deaths related to long-term exposure to $PM_{2.5}$ concentrations (53 per 100000 people).

Manoj Kumar & B. Srimuruganandam et.al (2019) conducted a study on the Health Effects of Particulate Matter in Major Indian cities and concluded that irrespective of health endpoints, the cities with high PM concentration and exposed population can lead to maximum hospital admissions and mortality. $PM_{2.5}$ and PM_{10} are observed to have elevated concentrations during a particular season, i.e. post-monsoon season The average IHD mortality in all cities is estimated to be 4079 and 3706 cases in the male and female populations respectively.

III. HEALTH RISK ASSESSMENT

The estimation of health risk assessment due to pollution has been performed using AirQ+ v.1.2 model (World Health Organization, 2016). AirQ+v.1.2 software adopts the risk of mortality of $PM_{2.5}$ with the impacts of long-term and short-term exposure on human health in a specific period. It works by logarithmic functions, matrix calculations, and statistical functions. Air Q+ v.1.2 provides the associated relative risks (RR) of exposure. The relative risk of exposure is defined as the incidence rate in the population exposed (number of new cases per 100, 000 population/year) with the incidence rate in the counterfactual population. The Air Q+ v.1.2 software uses WHO-specified input of relative risk (RR) values (per 10 g m–3) and their incidences for the different air pollutants as well as types of diseases (e.g., cardiovascular, respiratory, COPD, hospital admissions respiratory disease, etc.) (WHO, 2006; WHO, 2014). The health risk assessment is based on the population attributable fraction (PAF) which is defined as the fraction of health consequences of public exposure to a specific air pollutant (Maji et al., 2017; Khaniabadi et al., 2018). The PAF was calculated by the following equation (WHO, 2003):

$PAF = RR – 1/RR$ (in case of the total population exposed)

$PAF = p (RR–1) /p (RR–1)+1, 0 < p < 1$ (2) (in case of number population exposed) where,

RR is the changed relative risk for the health outcome,

p is the proportion of the exposed population.

$$RR = 1+ (Ca-Cw)\times(RR – 1)/10$$

where Ca is the ambient air pollutant concentration,

Cw is the WHO recommended threshold level of that pollutant.

In a specific population, the number of cases or the fraction of all cases attributable to a specific pollutant and health outcome is of interest to calculate the attributable burden (AB):

$AB = BoD. PAF$

where BoD is the total burden of a specific health outcome.

The total attributable burden for health outcomes of specific pollutants is the sum over all age groups:

$AB_{pollutant} = \sum$ all age group $AB_{pollutant}$ (health outcome, age group)

IV. METHODOLOGY

A. Study Area

It is the most populous state of India with a population of over 22.45 crores, i.e. approx. 17% of the total population of India (UIAI-GOI 2017) with an area of 2,43,290 km^2. Forest cover is 16,582 km2 (Anon 2017). The major sources of air pollution in UP are industrial emissions, transportation, waste and garbage burning, and road dust. Industrial emission is the biggest cause of pollution in Kanpur.

Table 1 List of cities in the study

City	Latitude(N)	Longitude(E)
Lucknow	26.847	80.9462
Kanpur	26.1197	85.3914
Agra	27.1767	78.0081
Ghaziabad	28.6692	77.4538
Gautam Buddha Nagar	28.3383	77.6078

This study attempts to investigate the effects of particulate matter especially $PM_{2.5}$ on the health of the individuals residing in the state of Uttar Pradesh by using AIRQ+ software and finding out the attributable burden of particulates on the health of an individual. The health risk assessment is based on the population attribute fraction (PAF) which is defined as the fraction of health consequences in public exposure to a specific air pollutant. Now it is required to find out the attribute burden of a specific health outcome of a specific pollutant over all age groups.

B. *Steps Involved*

Collection of data regarding death parameters from 2017-19 for the state of UTTAR PRADESH from GBD.

1) Calculation of annual average of $PM_{2.5}$ values for the state of Uttar Pradesh from 2017- 19.
2) Finding out the relative risk for exposure to a particulate pollutant.
3) Determining the population Attributable Fraction for the pollutant.
4) Finding out the total burden of a specific health outcome for the pollutant.

V. DATA COLLECTION

Data regarding the annual average concentration of PM2.5 for the various regions in Uttar Pradesh has been collected from Central Pollution Control Board (CPCB), Uttar Pradesh Pollution Control Board (UPPCB), National Air Quality Monitoring Program (NAQMP portal. (https://app.cpcbccr.com/state_CAAQMS/#/dashboard/landing/UPPCB)

Data regarding population for various districts of Uttar Pradesh has been collected from Census 2011 by the Office of Registrar General of India under the Ministry of Home Affairs and from the world population review.
(https://censusindia.gov.in/pca/Searchdata.aspx);

Data regarding deaths/Mortality, Disability-Adjusted Life Years, and Years Lived with Disability have been collected from the Global Burden of Disease (GBD) portal Under the Institute of Health Metrics and Evaluation (IHME) for the period of 2017-19 for various age groups starting from 25 and above with a class interval of 5 years exclusively. (https://vizhub.healthdata.org/gbd-compare/

VI. RESULT ANALYSIS

A. Stroke

The Burden of Disease (per 1,000,000 population) for Stroke for the year as per the GBD portal is 778.14, 797.63, and 791.56 for the years 2017, 2018, and 2019 respectively.

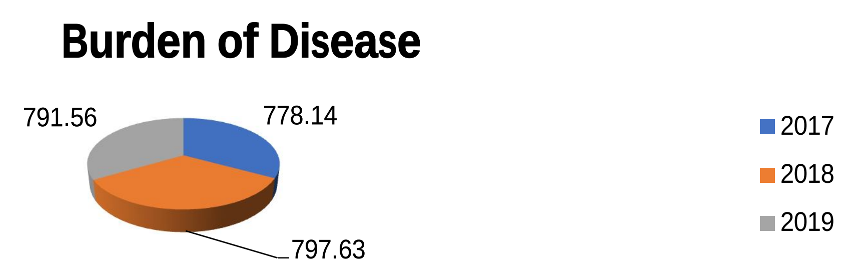
The values of relative risk (central) for stroke for the year 2017, 2018, and 2019 is 1.436, 1.429, and 1.388 respectively.

The Population Attributable Fraction for stroke for the years 2017, 2018, and 2019 is0.739, 0.729, and 0.668 respectively.

The attributable burden for the disease for the years 2017, 2018, and 2019 is 156538, 166881, and 188865 respectively which is a 6.6% increase and 13.17 % increase respectively in comparison to previous years.

Table 2

Year	Burden of Disease (Mortality per 1 lakh)	Relative Risk	Population Attributable Fraction	Attributable Burden
2017	778.14	1.436	0.739	156538
2018	797.63	1.429	0.729	166881
2019	791.56	1.388	0.668	188865



B. Ischemic Heart Disease

Ischemic heart disease (IHD) is a condition in which there is an inadequate supply of blood and oxygen to a portion of the myocardium; it typically occurs when there is an imbalance between myocardial oxygen supply and demand. The most common cause of myocardial ischemia is atherosclerotic disease of an epicardial coronary artery (or arteries) sufficient to cause a regional reduction in myocardial blood flow and inadequate perfusion of the myocardium supplied by the involved coronary artery.

The Burden of Disease (per 1,00,000 population) for IHD for the year as per the GBD portal is 28456.018, 28422.68, and 24687.86 for the years 2017, 2018, and 2019 respectively.

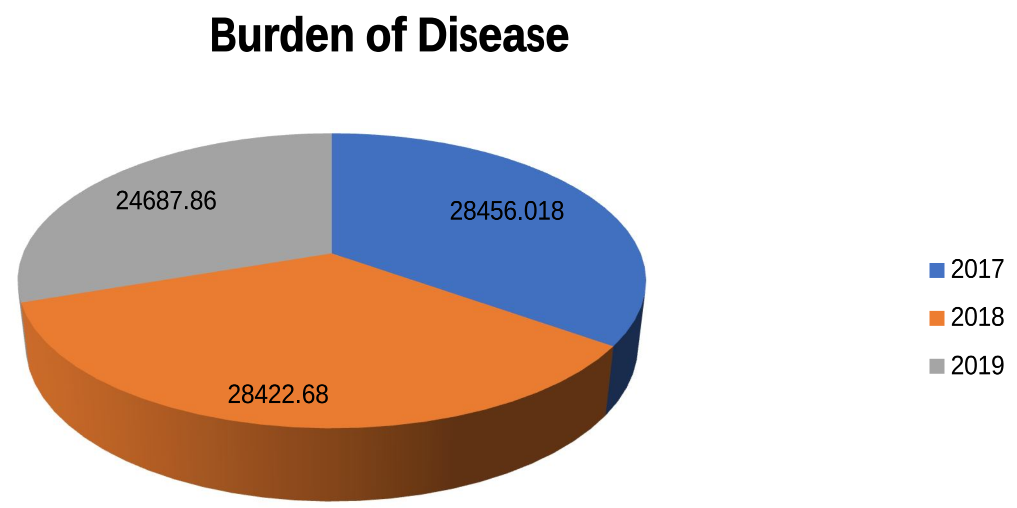
The values of relative risk (central) for IHD for the year 2017, 2018, and 2019 is 1.522, 1.528, and 1.646 respectively.

The Population Attributable Fraction for the IHD for the years 2017, 2018, and 2019 is 0.864, 0.873, and 1.038 respectively.

The attributable burden due to IHD is 24586, 24813, and 25626 for the years 2017, 2018, and 2019 respectively which is an increase of 9.23% and 3.27% respectively.

Table 3

Year	Burden of Disease (Mortality per 1 lakh)	Relative Risk	Population Attributable Fraction	Attributable Burden
2017	28456.018	1.522	0.864	24586
2018	28422.68	1.528	0.873	24813
2019	24687.86	1.646	1.038	25626



C. Lower Respiratory Infections (LRI)

Lower respiratory infection (LRI) is a broad terminology that includes acute bronchitis, pneumonia, acute exacerbations of chronic obstructive pulmonary disease/chronic bronchitis (AECB), and acute exacerbation of bronchiectasis.

The Burden of Disease (per 1,00,000 population) for LRI for the year as per the GBD portal is 89.359, 84.145, and 78.923 for the years 2017, 2018, and 2019 respectively.

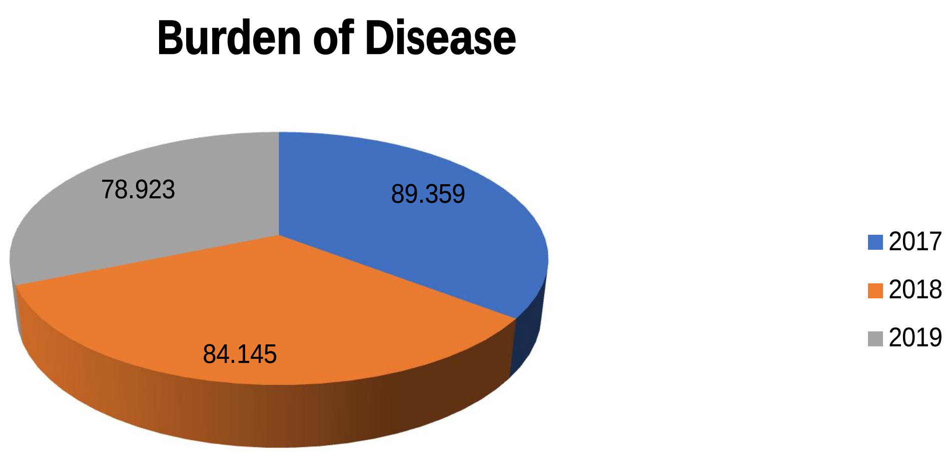
The values of relative risk (central) for LRI for the years 2017, 2018, and 2019 are 1.825, 1.815, and 1.701 respectively.

The Population Attributable Fraction for the LRI for the years 2017, 2018, and 2019 is 1.277, 1.264, and 1.113 respectively.

The attributable burden due to LRI is 9785, 9067, and 7747 for the years 2017, 2018, and 2019 respectively which is a decrease of 7.3% and 17.03% respectively.

Table 3

Year	Burden of Disease (Mortality per 1 lakh)	Relative Risk	Population Attributable Fraction	Attributable Burden
2017	89.359	1.825	1.277	9785
2018	84.145	1.815	1.264	9067
2019	78.923	1.701	1.113	7784



VII. CONCLUSION

The study has evaluated the trend and health effects of $PM_{2.5}$ in the state of Uttar Pradesh. The Indian economy and industrial, power generation, and transport sectors have grown considerably over the last decade. These increasing emissions of air pollutants have caused present-day concentrations of ambient PM2.5 and O3 in India to be amongst the highest in the world (World Health Organization 2018a). Exposure to this air pollution is the second leading risk factor in India, contributing to one-quarter of the global disease burden attributable to air pollution exposure (GBD 2016 Risk Factors Collaborators 2017, India State-Level Disease Burden Initiative Collaborators 2017). Air pollutant emissions are predicted to grow extensively over the coming years in India. Despite the importance of air quality in India, it remains relatively understudied, and knowledge of the sources and processes causing air pollution is limited. It is critical to understand the contribution of different emission sources to ambient air pollution to design effective policies to reduce this substantial disease burden.

Key sources contributing to the present-day disease burden from ambient PM2.5 and O3 exposure are the emissions from the residential combustion of solid fuels, land transport, and coal combustion in power plants. The attributable disease burden is estimated to increase in the future due to population aging and growth. Stringent air pollution control pathways are required to provide critical public health benefits in India in a challenging environment. A key focus should be to reduce the burning of solid fuels.

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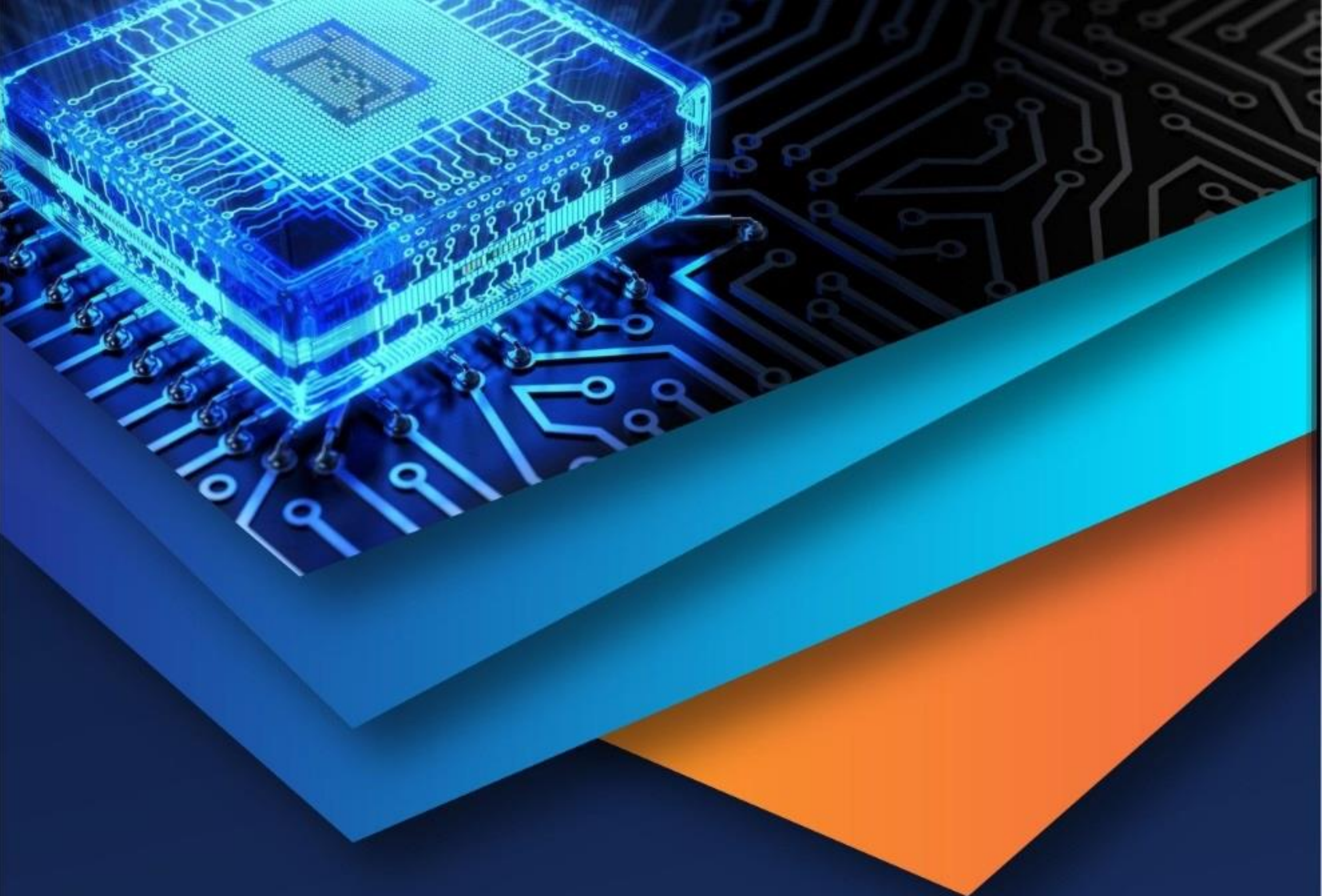

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