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Anthropocene Air Quality Impact on the Kolkata People

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Air quality is a significant concern globally, particularly in densely populated urban areas like Kolkata, pollution-wise the 2nd largest, fast-growing metropolis in India. The present study correlates to Kolkata city during the pre-Anthropocene (the 1950s) and the concurrent air quality related to human health. Investigating the impact of anthropogenic activities on air quality in Calcutta and Kolkata is relevant to understanding public health risks and environmental sustainability.

The portrayal of the current air pollutants, causes, classification and measuring apparatuses recommended by the India Meteorological Department, collected from WBPCB, the levels of the parameters such as. Particulate Matter ($PM_{2.5}$ and PM_{10}), CO, CO_2, NO2, O_3 and SO2 etc. and analysed statistically.

Air pollution has outnumbered the fatalities of other polluting agents such as waterborne, waste, radiation, and anthropogenic players in the 21st century. The novel insights into the specific effects of anthropogenic activities on air quality in Kolkata are the vulnerabilities of *transportation, industry, meteorological and slum activities that are valuable. The vulnerabilities that distract ambient air quality indices have reached critical levels* of air pollutants, especially particulate matter, GHG gases and NO_2.

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Different zones in the city are residential, commercial, shanty towns, and industrial areas. Results show levels of pollution are different in each area. Seasonal considered, the winter season is found to have the highest distraction from ambient air quality. Some suitable measures are conceptualised that will mitigate the menace of air pollution to pave the way for bringing sustainable urban health and environment development to Greater Kolkata.

Keywords: Air pollution; air quality index; health; population growth; Kolkata city.

1. INTRODUCTION

Health Research Institute (HRI) reports Kolkata is the 2nd largest polluted city in India and ranks 3rd in the globe (Delhi, Lahore and then Kolkata) and presently designated as the diesel capital, energy-guzzling, and mobility-rippled city. The persistent pollution increase from 1950 (start of Anthropocene) onwards affects human health and disturbs the disability-affected life years (DALY) are air, water, noise, soil and light pollution. The mass extinction on Earth was due to air pollution. Later it was reported the air quality Index (AQI) remained stable till 1850, up to the Industrial Revolution [1,2]. The anthropogenic activities later continuously augmented the AQI and have an increasing trend to date. The upper ranges of AQ not only threaten human life but are also apocalyptic to flora and fauna and in the blue domain.

According to IQAir, air pollution in Kolkata cosmopolis has been projected to cause 1,500 deaths/year and a fiscal loss thereof shall be USD 220 million. Kolkata (posthumous Calcutta) is a vast low land, now a cosmopolis that stretches adjacent to the Hooghly River and 1.5 and 9 m elevation. The city is among the four main metropolitan cities in India. It is one of the cultural and commercial hubs of the British in India. Presently Kolkata city possesses a yearly average of 84g/m3 of fine particulate matter (PM2.5) which is 17 times higher than the World Health Organisation's (WHO) safe limit and IMD reports Table 1.

The West Bengal Pollution Control Board (WBPCB) takes Observations of continuous air ambient air quality (CAAQ) for air quality parameters in and around Kolkata city are Ballygunge, Bidhan Nagar, Fort William, Jadavpur, Rabindra Bharati Univ., Rabindra Sarovar, and Victoria. The Parameters are PM 10, PM2.5, SO2, NO2, NH3, O_3, CO and C2 H5, hydro-carbons, Greenhouse gases(GHG,s), at various ranges and human impacts, Fig. 1 (a and b), and Table 1.

Kolkata, (22°30´ N. lat., 88°30´ E. long.,) has a major port entry (Haldia) in North Eastern India. It is 120 km from the Bay of Bengal and on the bank of the river Hooghly (Ganga) of area KMC: 206.08 sq. km; The climate is humid in summer with Thunder-storms and pleasant in winter with average rainfall 1400-1600 mm per year with maximum/minimum temperature 40°C and 10^0C. As per the 2011 census, the Kolkata Municipality population was more than 4.5millon with a floating population of 60000/day and the population density was 24,252 people/ sq. km. The various concentration ranges and related health impacts are in Table 2.

The present study is parameter-wise categorised (Table 2). The AQI observatories are taken at Victoria, Rabindra Bharati, Howrah, Haldia and Sidhu Kanhu indoor Stadium (https://aqicn.org/city/india/kolkata/us-consulate/). Haquem [7], has reported health-related diseases due to air pollution such as COPD and other acute respiratory infections (ARI) caused by air quality. His findings are respiratory diseases (85.1%), and later fragmented as ARI (60%), COPD, ((7.8%), upper track respiratory infection (UTRI) 1.2%, Influenza (12.7%), and AFBs (Acid fast bacillus) (3.4%), The latest AQI with weather data is in Table 3.

The Britannica has reported that air pollution in Calcutta has triggered potentially between the early 1950s and 20s of the 21st century. Calcutta in the 1950s, was using wood, dung, and oil as fuel, releasing dark smoke through chimneys and trams, man-pulled rickshaws and horse-driven vehicles with less pollution. In 2024, Kolkata ranks 2nd with an annual average of 84g/m3 of (PM2.5) which is 17 times the recommended WHO safe limit, India Today Web Desk, Aug 18th 2022.

The AQI report analysed for the cosmopolitan city Kolkata in Oct 2023 from 2019 to 2023 observed that PM 2.5 dropped during the years 2019- 2020 by 26.8% influenced by restricted mobility and closures (COVID-19). Later in the year 2021, the AQI increased by 51.7%. In the year 2022, the AQI decreased again in 2022 by 33.1%, whereas in 2023 it was surged by 40.2%. These fluctuations are prejudicated by parameters like O_3, P.M -2.5, P.M-10, NO_2, SO_2 and CO (mostly GHGs), Table 3.

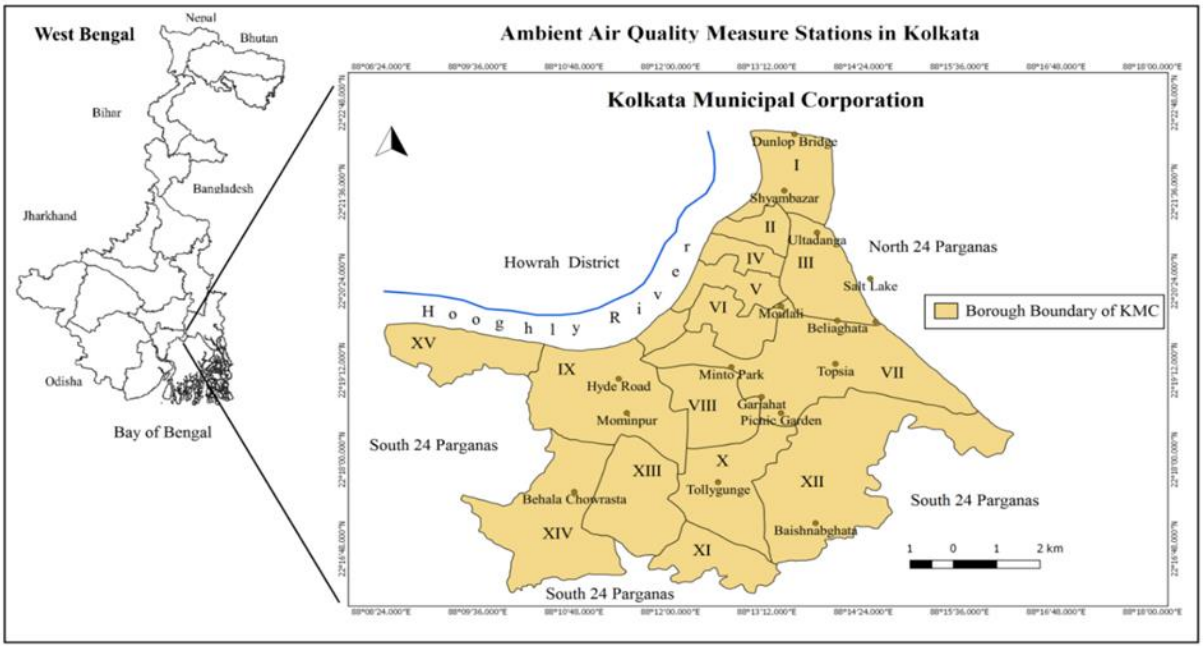


Fig. 1. Kolkata Municipal Corporation (KMC) featuring Air Quality monitoring Stations

Table 1. The air quality Index and the related health Issues (as Per IMD, WBCPCB)

Overall AQI range	The air quality	The related health issues
0-50	Good	The Impact is nominal, safe to live without breathing problem
51-100	Satisfactory.	May cause minor breathing discomfort to sensitive people.
101- 200	Moderate	Cause breathing uneasiness with lung, COPD, ARI, and cardiovascular diseases among the vulnerable group; children, geriatrics and comorbid patients.
201-300	Poor	Cause breathing discomfort to all on long-exposure
301-400	Very Poor	May cause respirational illness to diseased people on prolonged exposure. The impact becomes distinct with people with COPD and heart diseases.
401 and above	Severe	Even healthy people suffer from serious health impacts on comorbid people with lung/heart diseases,

0-50	51-100	101-200	201-300	301-400	401-500(+)
Good	Moderate	Poor	Unhealthy	Severe	Hazardous

Table 2. The AQI range & probable impacts on Human health in India: CPCB-2019

AQI size/ Hrs	Air quality /(respirable fraction)	Impact on Human Health
PM2.5 (≤ 2.5 µm dia. (24 Hours) (µg/m3)	1-30 (Good) 31-60 (Satisfactory) 61-90 (Moderate) 91-120 (Poor) 121-250 (Very Poor) 251 and + (Severe)	Carbonaceous organic/element $SO^{-2}{}_4$, $NO^{-2}{}_3$, Ammonium ion, Fe, Al, Ni, Cu, Zn &Pb particles that penetrate deep in the lungs, respiratory irritation, coughing, dyspnea, asthma, chronic bronchitis, irregular heartbeat, nonfatal heart attacks, death with heart or lung disease.
PM10: ≤ 10 µm. RSPM)(Respirable Suspended Particulate matter (thoracic fraction)	0 - 50 (Good) 51-100 (Satisfactory) 101-250 (Moderate) 251-350 (Poor) 351-430 (Very Poor)	Formed by mechanical coarse attrition of dust, lung deposition mainly by impaction, size 2.5 µm –10 µm are causing asthma, bronchitis, and heart attacks. Long-term exposure to high concentrations leads to lung cancer, chronic respiratory illness/allergies

AQI size/ Hrs	Air quality /(respirable fraction)	Impact on Human Health
(24 hrs) (µg/m3)	431 and + (Severe)	
PM0.1: (≤0.15 µm dia. Ultrafine Particles (UFP); (µg/m3)	large surface area to mass ratio due to potential carriers of harmful gases.	Long-term exposure to UFPs causes Heart disease, Myocardial infarction, Heart failure, Adult-onset asthma, and Chronic obstructive pulmonary disease (COPD). pulmonary inflammation, haemorrhage and even death.
NO_2 (Traffic related Pollutant) (24hours) (µg/m3)	0-40 (Good) 41-80 (Satisfactory) 81-180 (Moderate) 181-280 (Poor) 281-400 (very poor) 400 - + (Severe)	From vehicles to power plants, as fossil fuel emissions. NOx forms with H_2O, O_2 and other chemicals. That causes *acid rain/haze*. Short-term/high-level exposure causes asthma, coughing, wheezing or difficulty breathing, respiratory diseases, dyspnoea, broncho-spasm/ pulmonary oedema.
O3: Ozone (8 hours): (µg/m^3)	0 - 50 (Good) 51- 100 (Satisfactory) 101-168 (Moderate) 169 -208 (Poor) 209-748 (very poor) 749 - + (Severe)	Produced by photochemical reactions of O2, NOx, and VOCs Mainly from outdoor air, photocopiers, disinfecting, devices, air-purifying devices, and others. Cause, lung damage, asthma, DNA damage, and decreased respiratory function.
CO: Carbon monoxide, (8 hrs) Unit mg/ cum	0 – 1.0 (Good) 1.1- 2.0 (Satisfactory) 2.1-10 (Moderate) 10 - 17 (Poor) 17 – 34 (very poor) 34 - + (Severe)	Produced from stoves; fireplaces, smoking; generators and other equipment; outdoor organic burning, domestic and agricultural front. Fatigue, chest pain, impaired vision, reduced brain function
SO_2: Sulphur Dioxide (24 hrs); (µg/m^3)	0 – 40 (Good) 41- 80 (Satisfactory) 81 -380 (Moderate) 381 - 800 (Poor) 800 –1600 (very poor) 1601 - + (Severe)	Produced outdoors, stoves, waste burning etc. Causes loss of respiratory function, asthma, chronic COPD, Acute Respiratory, cardiovascular diseases etc.
NH_3: Ammonia (24 Hrs) ; (µg/m^3)	0 – 200 (Good) 201- 400 (Satisfactory) 401 -800 (Moderate) 801 - 1200 (Poor) 1201–1800(very poor) 1801 - + (Severe)	Causes chronic irritation of the respiratory tract. Chronic cough, asthma, and lung fibrosis. Higher conc. Can cause neurological symptoms like Impaired memory, brain edema, Intracranial hypertension, Ataxia, coma etc.
Pb, Lead Metals dust; (µg/m3)	0 – 0.50 (Good) 0.5- 1.0 (Satisfactory) 1.1-2.0 (Moderate) 10 – 3.0 (Poor) 3.1 – 3.5 (very poor) 3.5 - + (Severe)	Can cause Reproductive problems, High blood pressure, Kidney disease, Digestive problems, Nerve disorders, Memory and concentration problems, Muscle and joint pain, Cancer in adults etc.
Abb: other acute respiratory infections (ARI);. Ultrafine Particles (UFP; Chronic obstructive pulmonary disease (COPD).; volatile organic compounds (VOCs)		

Source: CPCB [3], Ohlwen et al. [4], Kwon et al. [5], Lu et al. [6]

Table 3. Kolkata Real-time PM2.5, PM10 air pollution level West Bengal; Last Update: 01 Feb 2024, 09:49pm Available:https://aqicn.org/city/india/kolkata/victoria/

Place	Air status	AQI- US	PM2.5	PM10	Temp (^0C)	Humidity (%)
Ballygunge	Poor	139	51	95	21	95
Chetia	Poor	129	47	88	21	94
Dhakuria	Poor	147	54	90	21	94
Fort William	Poor	155	63	87	21	94
Jadavpur	Poor	137	50	89	21	94
Kolkata Us Consulate	Poor	173	98	0	21	94
Kulia	Poor	159	71	83	21	94
Rabindra Sarovar	Poor	115	41	79	21	94
Tangra	Poor	154	61	106	21	94
Victoria	Poor	149	55	109	21	94

The identified populous areas in Kolkata city are Bally-gunge, Bidhannagar, Fortwilliam, Jadavpur, RBU BT road, RBS Sarovar and Victoria (Real-time air Pollution data). The AQI reaches diurnally peaks during the morning (6 AM) and evening 6(PM) and varies in the other periods. The AQI of Ballygunge remains always high [8]. There are 432 cars/km on Kolkata's road on average [9].

West Bengal as of date has 67495 companies including Corporate, Manufacturers, Exporters, Importers, Dealers, Distributors, Small and medium-sized enterprises (SMEs), micro-small-medium business houses (MSMEs), and Fast-Moving Consumer Goods (FMCG) Companies. Multinational Corporations (MNCs), LTD / PVT LTD / limited liability partnerships (LLPs) [10]. For the last three decades, the AQI has surged and turned apocalyptic.

Calcutta's 1850s had mainly pollution from coal-fuelled industries and the introduction of steam engines in railway (1855) added to COx pollution within the city then. Present air pollution in Kolkata is mainly by transportation due to old vehicles, fossil fuels (banned presently), less maintained motorised engines etc. adding to the concentration of Carbon Dioxide (CO2), air toxins, like Carbon Monoxide (CO), Hydrocarbon (HC), GHG gases, Nitrogen Oxide (NOx), and PMs of various sizes, Fig. 2(a) & (b).

1.1 Review of Literature

Air quality surge deterioration has impacted human health for two to three decades as per Epidemiological investigations. A rise in concentrations of ambient air particulate matter(Pm-2.5 and PM 10) is associated with a wide range of effects on human health, especially on cardiovascular diseases, chronic obstructive pulmonary disease (COPD), and acute respiratory infections (ARI), emphysema, asthma, lung cancer, etc. inviting pandemics like H1N1 or COVID-19, [12,13,14]. The Hindu reported that only air pollution in India caused 2.18 million deaths/annum on 30th Nov 2023. Globally the number of premature deaths due to air pollution is 4.8 million/per annum (World Health Organisation 2022 [15]). Kolkata live in an atmosphere with ambient Aerosol (PM2.5) concentrations exceeding the average concentration of 5µg/m^3 [15]. The current WHO guideline for an annual average conc. of 5 µg/ m^3 (WHO, 2020, 2022). PM2.5 only causes 4.2 million deaths and ~103.1 mil. disability-adjusted life-years (DALYs) globally [16].

The pandemic, COVID-19 was apocalyptic but a boon to improve the air quality of most megacities of the globe including Kolkata City, India. Open-air waste burning, construction, road activity, crowd dust, firewood, vehicular exhausts, thermal power generation, Diesel generator sets, and industrial blast furnace fumes, [17,18,19,20].

The vulnerable groups are the infants, paediatrics, geriatrics, comorbid and urban masses are most vulnerable to health impacts due to high AQI [21,22,23,24,25]. During the pandemic, SARSE Covid-19 impositions (Mar 24th –May 31st, 2020) there was a depletion in AQI in an average was 53.61% [19,26,27,28]. Indoor air pollution (IAP) can be checked by potential pollutants like DG sets, zero cattle sheds, wood cooking, and agricultural waste burning.

(a)  (b) 

Fig. 2(a). Howrah Calcutta, Glenn Hensley, Photography (1944) (b) Traffic jam during Puja days 2023 [11]

Air pollution has emerged as a major alarm for all countries due to its disastrous impact on mortality and morbidity in urban rather than rural areas [29]. Kolkata city is a very old city (of 2000 YBP) but became important after 1717 after Warren Hastings shifted all its administrative offices to present Kolkata city. COVID-19, COPD, Haze in the evening/dawn, CVDs (cardiovascular diseases, and breathing difficulties in crowded areas have shattered Kolkata city. It is pertinent to keep the air quality level at a safe limit. So, the various parameters that cause air pollution in Kolkata are to planned for our future generation.

1.2 The Bjective

The study aims to find out the actual conditions of air pollution and air quality of Kolkata and also find out different types of measures taken to control the pollution. The objective of the study is:

i. To have an assessment of the impact on Human health due to air pollution.
ii. To spread awareness among the slums and citizens of Kolkata about the negative effects of air pollution.
iii. To possible measures to control air pollution appraising the pollution control guidelines related to the health issues.

2. METHODOLOGY

Air pollution constitutes Ambient air pollution and Household air pollution. The prime bases of anthropogenic air pollution are fossil fuel emissions, specks of dust from traffic, construction sectors, manufacturing, power generation and chemical units. The areas responsible are the chemical and fertilizer industries, metallurgical and other industrial plants, and, finally, municipal incineration plants, Stadiums (Indoor and outdoor), and domestic areas The transportation sector with solid waste burning within the city's highest for Kolkata city.

The Central Pollution Control Board (CPCB) Govt of India (GOI) through a National Air Quality Monitoring Program through NAQMP observes air quality data like PM2.5, PM10, and NO_2, SO_2 monitored and analysed. The data used are the NAMP manual monitoring network (https://cpcb.nic.in/namp-data/), CAAQM continuous monitoring network from the Central Control Room for Air Quality Management website, Fig. 3. (https://app.cpcbccr.com/ccr/) and, https://aqicn.org/city/india/kolkata/victoria/

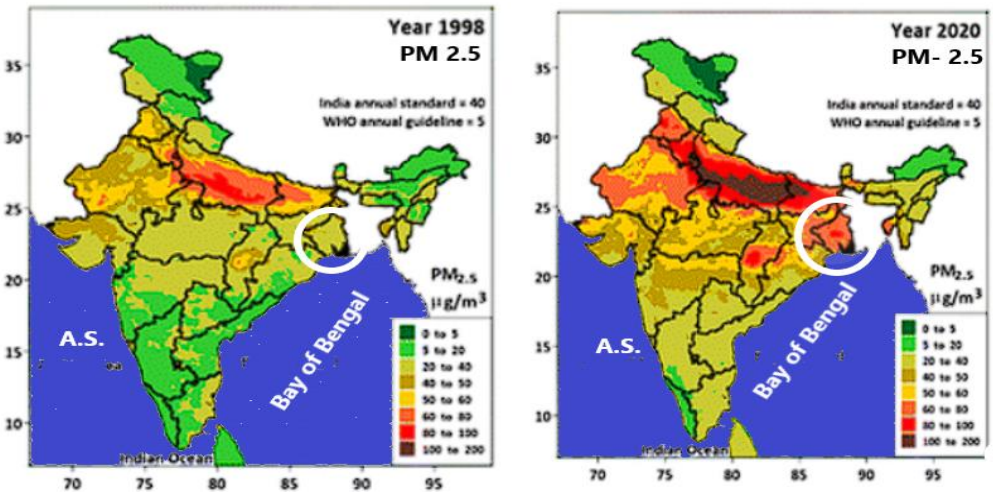


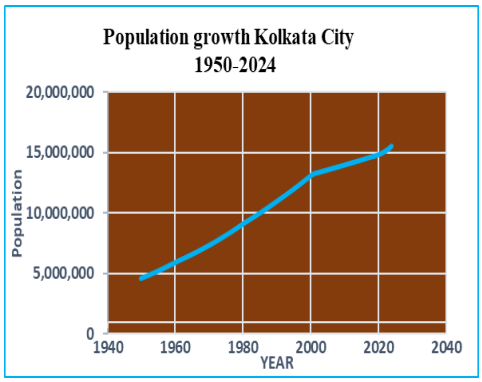
Fig. 3. Kolkata Municipal Corporation (KMC) showing the air quality index changes from 1998 to 2020 (source: [30] modified)

Fig. 4. The Workflow diagram of air quality trend in Kolkata city

Table 4. The principle and instruments used for measuring air pollutants, (Source: CSTEP [27]. IMD EMRC (SOP) [31]

Source Emission	Symbols used for	Formulae used	Instrument used by IMD at Delhi(Tool Kit)
Transportation (PM 2.5/ PM 10/ NO_x/ SO_x)	VKT_{ij}=$Vehicle\ travel\frac{km}{day}$: RL = $road\ length$; E = total emission; n = $No\ sectoral\ unit$: EF= Emission Factor(action wise)	$VKT_{ij} = RL_j * n_i$ $E_j = EF_i$	Continuous Ambient Particulate Monitor (SPM) PM10/PM2.5 head (Model FH 62 C14 Series); NOX Analyzer (Model 42i-B-Z-M-S-D-C-A)
Industries	F=Fuel consumption (MT/day)	$E = F * EF$	CO Analyzer (Model 48i-Z-S-C-A);
Construction	A=Area of construction d = Activity period (day or hrs)	$E = A * d * EF$	Gas & Dust Sampling System (TFS make)
DG sets	C= Installed capacity(KVA) h = Hours run	E = C*h* EF	Black Carbon Analyzer Model: AE31
Domestic Fuel burning	P =population H= % house using fuel like kerosene, LPG or firewood; c =per capita fuel consumption Mt/day;	E =P*H*c E = F ×EF	Gas & Dust Sampling System Magee Scientific
Solid waste burning	Q = Quantity of waste burned	E = Q * EF	CO Analyzer (Model 48i-Z-S-C-A);
Re-suspended dust	k= Particle size multiplier SL = silt load (gm/cum) W = Av wt. of Vehicle	$[E = VKT *$ EF] $EF_{road\ dust} = [k * SL^{0.091} * W^{1.02}]$	Gas & Dust Sampling System (TFS make);
Aviation and ports	N = No of units of flight or shipment	E = n* EF	NOX Analyzer (Model 42i-B-Z-M-S-D-C-A); O3 Analyzer (Model 49i-B-3-N-C-A);

(a)



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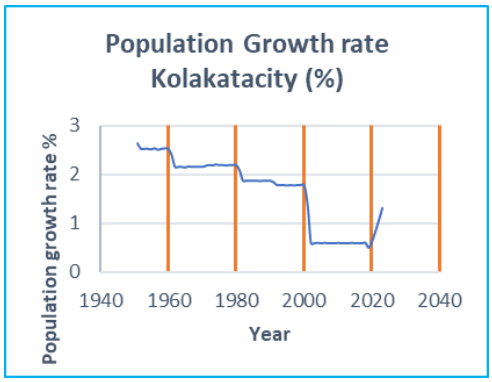


Fig. 5. (a and b). The population Kolacota (a) Population wise (b) the growth rate wise

The ambient air quality data in Kolkata is observed by the WBPCB, the Central Pollution Control Board (CPCB), by 17 monitoring stations, analysed and compared the average value with the NAAQS standard and published on its website, Fig. 4. CPCB categorise them as low, moderate, high and critical. The raw data needs conversion to an air quality index (AQI), analysed and correlated with the human impact on Kolkata (Table 4).

2.1 Population changes in Kolkata City

Kolkata is the employment hub of the eastern and northeastern states of India. It is the epicentre of transport, communication (road, air, navigation) and business of NER, Tripura, Odisha and Bihar Fig. 5 (a & b).

The Kolkata Municipal Corporation (KMC) with an expanse of 206.08 sq. km, has a population of 4.5 mi.+ daily floating population 60000/day, (2011 census). As Kolkata Municipal Authority (KMA) comprising of KMC and its suburbs accommodates 15.57 million people, (a population growth rate of 1.55%, in 2024), Dataful.com, www.census 2011.co.in/census/metropolitan/184-Kolkata). (Fig. 5(a&(b)

Sources of air pollution, some noxious emitted air pollutants affecting human health are particulate matter (PM2.5 and PM10), Carbon monoxide (CO) and Ozone Nitrogen dioxide (NO2), Carbon dioxide (CO2), Oxides of Sulphur (SOX), Oxide of Nitrogen (NOx),), ammonia, benzene, volatile organic compounds (VOCs), radon, toxic metals, and microorganisms Table 5.

2.2 Major causes of air Pollution in Kolkata

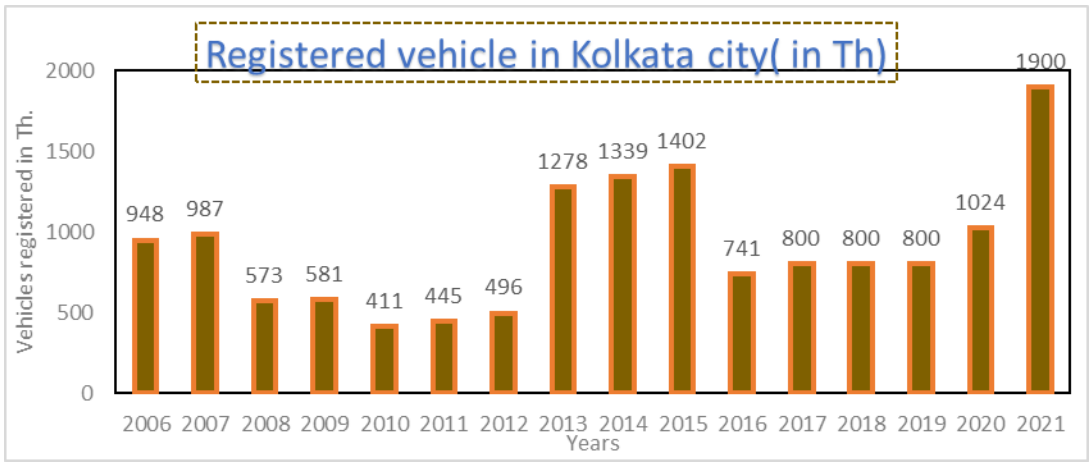
The main causes of high air pollution in Kolkata are meteorological, transportation, solid waste burning, domestic fuel for cooking, Industries, DG sets, construction and aviation etc. Air pollution in Kolkata is due to transportation (51.4%) followed by industry (24.5%) and dust particles (21.1%). In 2022, 21.8 lakh vehicles were registered in Kolkata, India, up from 19.86 lakh in 2021 and 18.72 lakh in 2020. In 2021. As of August 2023, Kolkata has about 45.3 lakh vehicles on 1,850 km of road space, with 6.5 lakh two-wheelers and 10.7 lakh four-wheelers. Kolkata has the highest car density among metros in India, with 2,448 cars per kilometre. In the Pandemic period (March 2020 and May 2022), the number of vehicles registered has surged in car ownership (78102 numbers) instead of the increasing bus to cater to the huge volume of commuters [39].

It is found that the number of motorised vehicle accidents in Kolkata city in 2022, due to cars was 61 deaths, buses, with 60 accidents, and trucks with 53 [40,41]. In 2021 and 2022, the number of Road accidents 1777 and 1948 and deaths that occurred were 196 and 185, injuring 1418 and 1718 respectively [41]. In ranking it is in 16th position, yet most of the fatalities are due to bad climate and visibility [42], Fig. 6 (a & b).

Table 5. Other parameters observed in Kolkata City that affect air pollution.

Parameter s	Sources	Receptor	Human Impact
VOCs/ VVOCs / SVOCS: very /Semi-Volatile volatile organic compounds	Cooking, smoking, indoor chemical reaction, cleaning infiltration, air conditioning, ventilation system and construction materials	Inhalation, ingestion, or dermal contact.	Eye, nose, and throat irritation; headaches, nausea; and damage liver, kidney, or central nervous system. Even carcinogenic
Aerosols (Primary/ Secondary)	Originating from different indoor sources/indoor gas-to-particle reactions	exposure through inhalation	Affects the lungs and other target organs, (the heart and brain)
Toxic metals	Non-carcinogenic: Co, Al, Cu, Carcinogenic: Ni, Pb, Fe, Zn As, Cr, Cd,	inhalation, ingestion, or contact,	cardiovascular disease, slow growth, and damage to the nervous system
Pesticides (control and prevent pests)	Inorganic/organic pesticides used for bacteria, fungi, insects, rodents, and other organisms	Dermal uptake, ingestion, inhalation	Short-term skin and eye irritation, dizziness, headaches, and nausea; Long-term chronic impacts, such as cancer, asthma, and diabetes
Radon's	construction materials, soi pore l gas, and tap water	contact	indoor radon causes lung cancer risk to rise of high 3% to 14%, and radon level
Biological Allergens	Animal excreta, cat saliva, house dust, mites, cockroaches, and pollen & microorganisms	Inhaling, contact	Sensitization, respiratory infections, respiratory allergic and wheezing
Building-related illness (BRIs)	Exposure to inorganic, organic, physical, and biological contaminants,	inhalation, ingestion, or dermal contact,	Irritation of eye no end throat, fatigue, headache, mental, dizziness, Asthma, skin dryness, etc
Sick building syndromes(SBS)	Localized but duration of exposure,	inhalation, ingestion, or dermal contact,	Toxic and irritant, flu, g fever, chills, chest pain, muscle aches, cough, lung, respiratory problems

Source:www.pca.state.mn.us/pollutants-and-contaminants/volatile-organic-compounds-voc; Zhang et al. [32] Seltzer et al. [33] .USEPA [34], Tran et al. [35], WHO's Handbook 2009 [36] Gerardi et al. [37] Shilpa et al. [38]



6(a)

6(b)

Fig. 6(a & b). The number of vehicles registered (2006-2021); Fig. 6 (b) Registered Private cars in Kolkata

By 2025, the Kolkata Municipal Corporation (KMC) area due to its agglomeration is expected to exceed four million motorised vehicles over 1860km of roads. The West Bengal Electric Vehicle Policy (WBEVP) of 2021 inspires the formation of exchange stations for two or three-wheelers [43].

2.3 Kolkata Municipal Air Pollution

The Kolkata Municipal Corporation (KMC) covers an area of 187.3 km2 and comprises 141 wards extended to 15 boroughs. As per the Census of India (2011), the population of KMC in 2011 was 4496694. The density of the population in the city is 24252 per sq. km., housed on the banks of the Hooghly River.

The temperature of the city ranges from 10° C to 40° C. The Central Pollution Control Board (CPCB), in the 1980s, initiated national ambient air quality monitoring (NAAQM) at the national level to regularly monitor the ambient air quality of selected major urban cities and industrial towns of the country. Later renamed as the National Air Monitoring Programme (NAMP). Howrah while Haldia and Durgapur were subsequently added to the network. The West Bengal Pollution Control Board (WBPCB), under NAMP, is monitoring the ambient air quality of major urban towns and industrial areas of the state in the district of Kolkata for 17 stations/ daily.

2.4 Meteorological Air Quality Changes

As per (NAQI) followed in India the ambient air quality index of Kolkata remains “poor or very poor or severe” category from 18 to 20 days in winter being influenced by meteorological events with high PM and NO_2. On 8.10.2018, the Aq of Kolkata exceeded the NAAQS)for Kolkata, it was due to meteorological events. So WBPCB takes yearly observation for Kolkata city in the stations such as Picnic Garden, Tollygunge, Hide Road, Behala, Baliaghata, Topsia, Vaishnav Ghat, Ulta Danga, Momin pore, Mullaly, Shyam Bazar, Garia Ghat and Minto Park for PM2.5, PM10, NO_2 and SO_2. The dusty city Kolkata reaches its peak in winter under the worst polluted traffic intersections, Fig. 7. www.macrotrends.net/cities/21211/ calcutta/population.

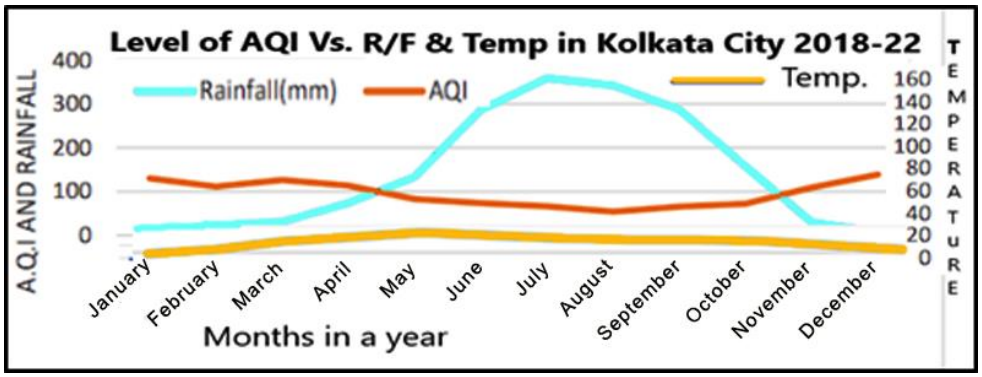


Fig. 7. Relation between AQI and meteorological (R/F & Temp) Kolkata city
Source: [20]

The NO_2 Concentration in the Kolkata sky is higher due to Kal Baisakhi. The troposphere acts as a sink for NO_X. There is a constant transfer of NO_x from the stratosphere to the troposphere in the tropopause as a subtropical Jet. The reactions change day and night [44,45,46]. The daytime reactions are

During day O3 + hv (λ < 340nm) → O(„D) + O2 (1)

H2O + O(„D) →2OH + 2O2 (2)

OH + NO2 +M → HNO3 (3)

HNO3 + hv (λ < 420nm) → HO + NO2 (4)

NO2 + O3→ NO3 + O2 (5)

and photolyzed in day rapidly as

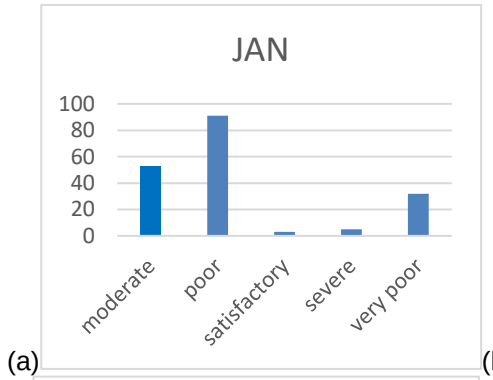
NO3 + hv (λ < 590nm) → NO2 + O ("P) (6)

Where

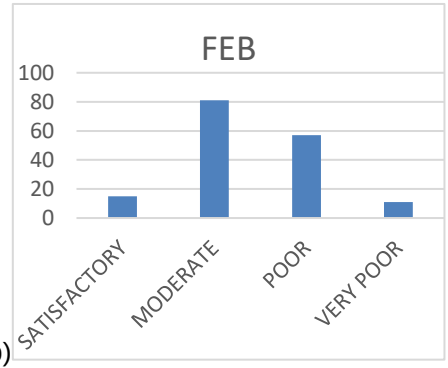
[O(„D) and O ("P) are highly energised and ground state oxygens

2.5 Air Quality monthlies in Kolkata (2015-2023)

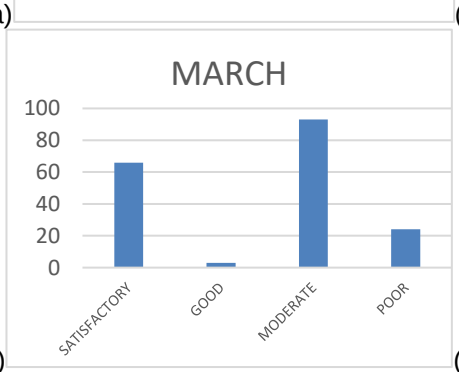
AQI level in Kolkata May 2015 to 12 November 2023) has been taken and the variation in quality is given 6(a-l).



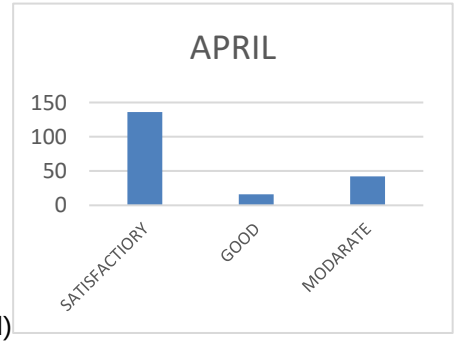
(a)



(b)



(c)



(d)

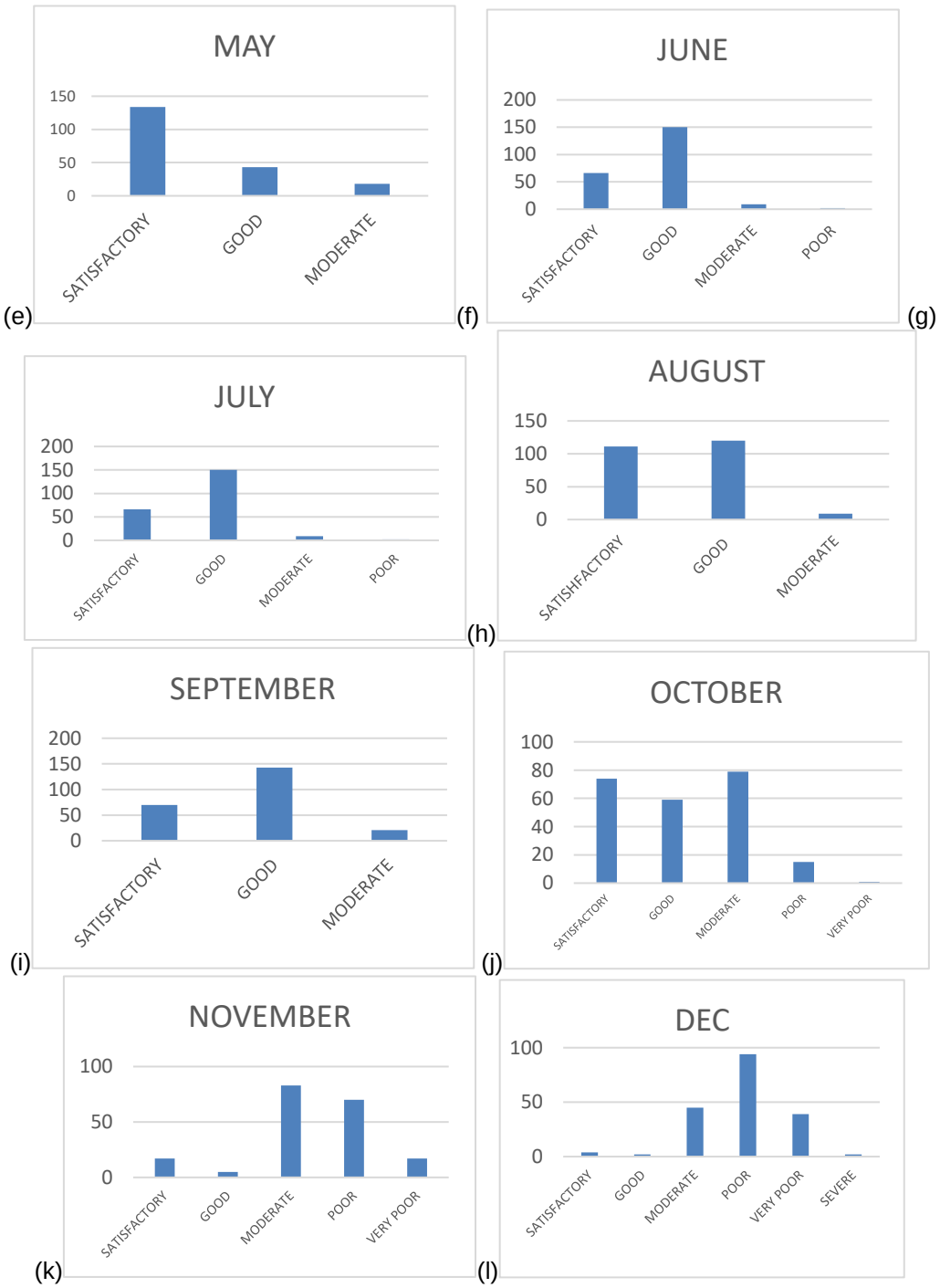


Fig. 8(a-l). The AQ month-wise from May 2015 to 12 Nov 2023 (source: Dataful)

The AQI is becoming the worst in January. Remined moderate in Feb and March. Many days remained satisfactory during April and May. The AQ remains good to satisfactory from June to Sept., and later the air quality worsens. *The air pollution of Kolkata city worsens in winter months when typical weather conditions like temperature inversions entrap pollutants in lower levels of the atmosphere*, Fig. 8 (a to l).

2.6 Meteorology Events and Air Quality in Kolkata:

The EMRC (Environment Monitoring and Research Centre), IMD, EMRC observes the atmospheric air quality constituents that change

the climate such as depletion of the global ozone layer, and the air quality constraints from regional to global scales. Meteorology plays a pivotal role in the concentrations of parameters in air pollution. During heavy rainfall and strong winds, emissions reduce pollution concentrations. In the winter there exists a lowering of temperatures and inversion that has more impact on emissions. Low temperatures also increase emissions due to the burning of husks and warming [42,47].

2.7 Respirable Particulate Matter

The Respirable Particulate Matter (RPM) includes noxious materials for human breath such as smoke, dust, and soot particles which shall be < 10µ (microns diameter). The Air Pollution Index (API) are: PM10, CO, NO_2, O_3 and SO_2 includes High volume samplers, Handheld devices, Passive monitoring, Continuous monitoring and Active sampling using silica gel. Haque [7] study revealed respiratory diseases (85.1%). have overweighed waterborne diseases (14.9%) after 75 years of the Anthropocene.

2.8 Interpreting Health Outcome of Surveyed Dispensary in Kolkata

According to a health survey at dispensaries owned by Kolkata Municipal Corporation (KMC), the major challenge for healthy living. It is observed that the short-term health impact due to RPMs is the estimated number of attributable cases of Epithelial sodium channels (ENaCs) like chronic bronchitis in adults and children. The fatalities rate, due to PM2.5 on ENACs are COPD for adults, acute lower respiratory infections (ALRIs) in children (0-5 years of age), lung cancer, and stroke for elderly geriatrics [48], Fig. 9 (a-d).

Two healthcare units are identified for the primary survey board on pollution level data. e.g: Behala dispensary. As the concentration of S02 remained low across the monitoring stations and no single station was under moderately low pollution categories. The information gathered was that about 80% of the respondents were from slums, single-room occupants. They use kerosene stoves, (37.3%) followed by LPG (30.3%) and rest outside open hearths.

The respirable particulate matter and the suspended particulate matter have a declining trend during 2000-2011 i.e. the first decade of the 21st century, Fig. 10 (a to d).

2.9 Indoor and Outdoor Pollution Averting Activity

The building-related illness BRIs) and Sick Building Syndrome (SBS) are two Indoor air pollutants. Indoor air pollution was noticed among the slum-dwellers. However, the level of indoor pollution is not observed by any agencies. WHO ranked urban outdoor air pollution as the tenth leading premature death. Indoor air pollution is the fourth leading cause. The Ultadanga dispensary revealed that 96.4% of them do not prefer to remain inside to avoid outdoor pollution, 75 % do not prefer to avoid busy roads during busy hours., and 71.4 % do not avoid garbage and landfill disposal sites.

2.10 Diseases Analysis

The dispensaries Behala and Tangra dispensaries have recorded more than 90% of the respondents with respiratory diseases. while Ultadanga dispensary has recorded 71.4%.in Ultadanga dispensary, among the respiratory diseases, the patients with (ARI) contributed 21.4%, CPOD constituted 10.7% influenza constituted 35.7%, and UTRI constituted 3.6%, respectively .in Behala dispensary respondents with ARI comprised 72.4% COPD comprise 10.3 and acid fort bacillus (AFB) comprise 10.3% (TB and Leprosy). It is difficult to link the intensity of pollution and any disease.

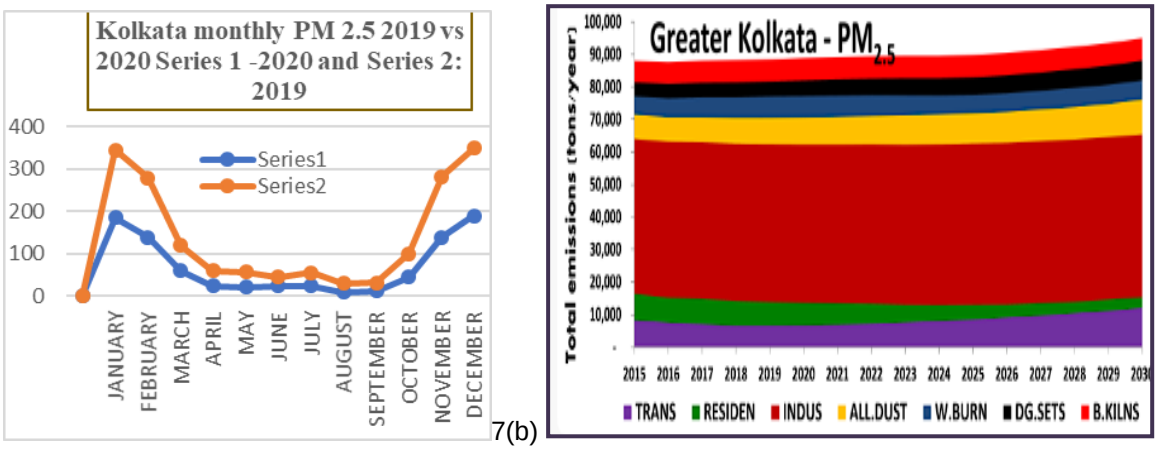
2.11 COVID-19 Lockdown and Kolkata's Air Pollution

WHO reported Kolkata (India) ranked 25th amongst 1100 cities in the world. Restrictions on transport, Industries and outdoor activities have reduced the pollution level in Kolkata. The pollutants $PM_{2.5,}$ and PM_{10}, as per National Air Quality Indices (NAQIs) pre and post-COVID-19 lockdowns in Kolkata have reduced the pollutants, along with pollutant data. SO_2, CO, NO_2, and NH_3, exhibited drastic variation. Bera et al [49]. The greater, Kolkata saw a big improvement in air quality during the covid 19 lockdown. But thereafter, Kolkata's pollution levels started rising in winter. *PM2.5 levels particularly rise in October, and remain high until March of the next year. The COVID-19 has a temporal declining impact on air quality.*

2.12 Concentration and Trends of Ambient air Quality

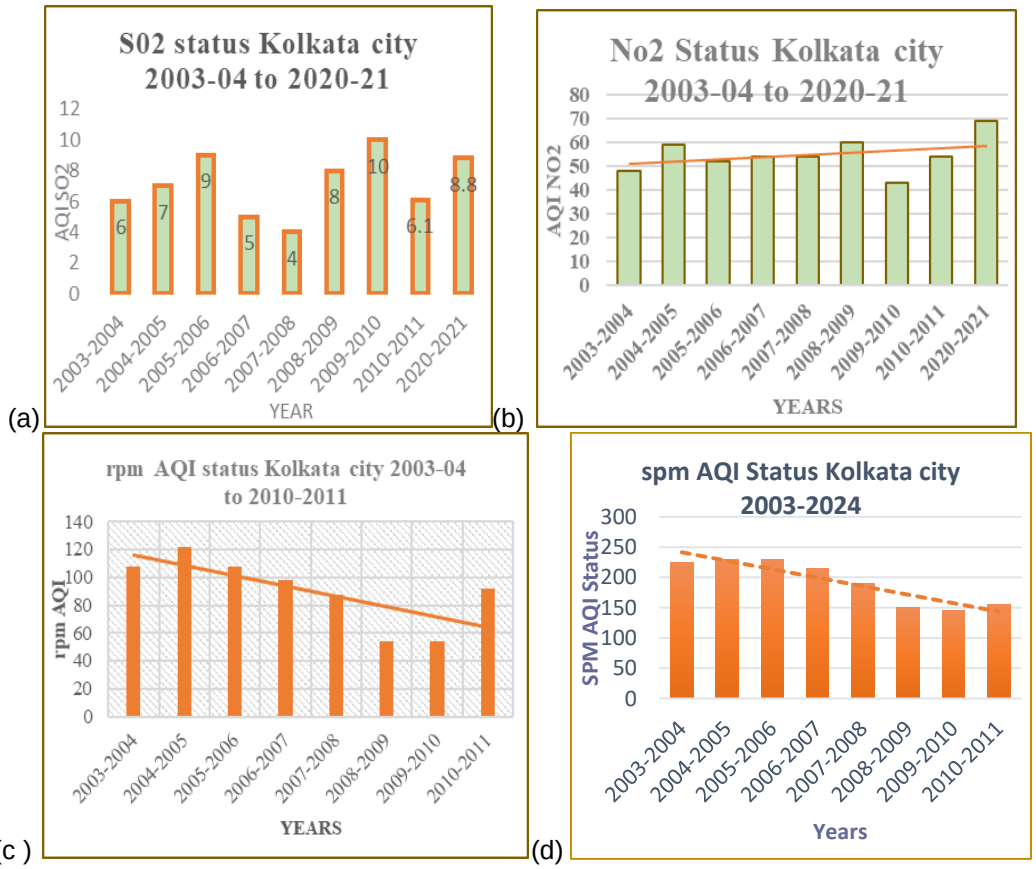
Among the air pollutants, the concentration of PM2.5 affects the national Ambient air quality

(NAAQS) i.e. 40 µg/ m^3 for five to six months/year (Oct to March) as per CPCB data. The monthly average concentrations of pollutants NO2 and PMs record high during winter months (Nov and Dec). and the value reached two to three peaks in January due to climatological and meteorological events. During winter the vertical movement of winds gets stopped due to the pressure variation (most probably high pressure on the ground) and the pollutants at ground level.



7(a) 7(b)

Fig. 9(a and b). The AQI of Kolkata city for PM 2.5 (2019 and 2020) and projected PM 2.5 up to 2030. (Source: AQ for Kolkata (Calcutta), India, Available:https://urbanemissions.info/india-apna/kolkata-india/)



(a) (b) (c) (d)

Fig. 10 (a-d). The trend in parameters that affect the air quality of Kolkata city

3. DISCUSSION

The concentration of RPM and NO_2 in the ambient National Ambient Air Quality Standards (NAAQS) i.e. National Ambient Air Quality Standards. During winter days the thermal inversion occurs due to depleted radiative heat, which causes the upper air PM2.5 to surge as per the West Bengal Pollution Control Board [50] due to strong westerly wind causing heavy fog (haze of smog) blanketing the city and raising COPD cases.

3.1 Health Impact

SARS COVID-19 has shattered the life of Kolkata due to the shutting of Industries, transport, education, and social connections, (enforcing strict quarantine, Lockdowns, social distancing, and closing economic activities from 24th Mar 2020 to 3rd May 2020. The major air pollutants like PM2.5, PM10 and NO2 were about 58.71%, 57.92% and 55.23% near Rabindra Bharati University but there was constant emission of PM2.5, After 1919, Kolkata has never faced any pandemic till 2020. But with all medical amenities and its government set up, Kolkata city only has 126,421people and 3040 deaths (data as of 15.01.2021) which is the highest in West Bengal ever faced after 1900, [51,52].

PM10 and NO2 were recorded around the Kasipur Cossipore thermal power station. As per World Bank blogs In India, air quality has been improving despite the COVID-19 lockdown [53]. Open air quality is essential to human health as a healthy person inhales ~ 14,000 litres of air/day. It is pertinent that the air in the city must be safe for one's health, the ecosystem and the environment.

Indoor air pollution (IAP) is unwanted for urban people who remain inside their houses, and occupants' activities. biomass smoke, cooking, stoves, diesel generators, various electronic gadgets, smoking, paints, chemicals, etc. There is an increase in Carbon monoxide (CO), aerosol, particulate matter (PM), and volatile organic compounds (VOCs). , biological pollutants, and others. So the pollution in Kolkata makes its inhabitants of slum areas suffer from COPD, ARI and other respiratory diseases [35].

One can protect oneself if the person reduces exposure time at high AQIs and reduces the amount of time and the intensity of outdoor activity when the AQI is high, especially for comorbid. To reduce air quality, as per Rules 4(1) of PWM(Amendment) Rules, 2022" Carry bag and commodities made of virgin or recycled plastic materials and the general public should not to use of plastic carry bag shall not be less than one hundred twenty (120) microns in thickness with effect from the 31st Dec. 2022".

Kolkata City and its sub-urban areas observed a big development in air quality levels during COVID-19 restrictions. Thereafter, air pollution levels started surging in winter (Nov to March) whereas the. PM2.5 levels started rising in October. The monthly AQI ranges from moderate to satisfactory in most of the urban areas of West Bengal. But during the peak of the pandemic (the year 2020), the AQI was reduced to 179 in Kolkata and 180 in Howrah maintained below the AQI value of 200 (safe). With more shanty towns under poor dwelling conditions, more awareness to be created to avoid air pollution. The shared kitchen within the living room is common in slums and is the major cause of indoor pollution [7,54,55].

Respiratory diseases are the result of poor air quality. They are ARI, COPD, influenza, Upper Respiratory Tract Infections (UTRI), bronchitis, asthma, pneumonia, and Acid-Fast Bacilli (AFB). The challenges are enhanced and vulnerable to fatalities if the patient has comorbid diseases. Recent studies reveal that ARI is the dominating disease among all stated above due to poor air quality [56,57].

The doctors should come forward to give standing to the spate of addressing respiratory health issues. Vaccines and medical interventions are to be developed to fight the viruses, bacteria and micro-organisms.

An innovative model framework is to be developed in greater Kolkata to reduce slum growth, and simultaneously give importance to citizen's health and occupancies. They integrate to resettle the marginalized communities to bring these communities to the mainstream of the city. The holistic transformation of slum areas, developing in the greater Kolkata city, should take care of the transformation of these shanty towns with minimum WASH standards. The diseases caused on account of polluted air need sufficient research and adaptations in medical healthcare infrastructure and awareness. The zero slum as per *SDG-11* should focus on WASH facilities, land rights and more housing facilities to create a sustainable environment.

Understanding the cause, the health impact of emissions, and exposures to polluted air in the concurrent growth of highways, motorised vehicles on roads, water and airways, houses, KMC's waste management area, and industries, can deliver solutions to ameliorate the impacts of multipollutant on greater Kolkata air quality

3.2 Suggestive Measures for Health Issues in Kolkata City to Reduce AQI

"Understanding the local air quality causatives and their impact on human health and their susceptibility to Kolkata cosmopolis by reducing pollutants like carbon and CFCs, (SDG-3), Ghosh et al. [56] https://www.biomedcentral.com/collections/apah. " Some of the major AQI-reducing measures are

3.3 Measures for Various Sectors

a. For the transportation sector: Substituting or retrofitting existing buses with diesel particulate filters DPCs and all petrol and diesel vehicles to run with either CNG or electric and ban on petrol and diesel vehicles. Use of filters and scrubbers in cars and factories' chimneys to enhance air pollutants. Office-going staff should avoid personal automobiles and use public transportation, common pull or carpooling.

b. **From domestic sector pollution:** stopping use of solid fuel and increase of LPG connections for cooking and use of inverters in place of diesel/petrol driven generators.

c. **Open waste burning practices:** Open waste burning in the open air is an old practice in Kolkata city. Proper open waste collection, carriage, and management systems as per the Solid Waste Management Act 2016 CPCB. Build innovative solid waste management and ban/reduction on open waste burning

d. **Pavement and building construction dust:** Kolkata is an age-old city with congested horizontal growth, but vertical expansion has recently surged in by dilapidating old mansions and rebuilding multi-storied buildings. The dust generated by dilapidation and construction is noxious and air-polluting. The current guidelines on pavement and building construction need strict adherence.

e. **DG sets operation:** ban all DG sets on sale and operation within the city.

f. **Regular monitoring** to develop measures and/or evaluating, analysing exposure saving approaches and recording for future policy making.

g. **Green-based solutions:** More trees, more grass, green buildings, solar panels, electric vehicles, zero coal/fossil fuel power plants, diversion of traffic in lonely roads, waste management etc can reduce air pollution.

h. **Regular training:** widespread among the citizens of Kolkata the air pollution agents and even it should be cultivated among the children at primary through their curriculum as the impact of air pollution on human health is apocalyptic.

i. **Carbon credit/ carbon tax:** Practices of benign nature-based carbon credit generation and use of carbon tax in Calcutta agglomeration is the latest methodology that can be inculcated in all factories, industrial units and Kolkata Municipal corporation which must be implemented.

j. **Zero slum approaches:** Shanty towns in Cosmopolis in Kolkata city, are one of the key causes of air pollution. Rehabilitation in situ, Resettlement in suburban areas, and satellite towns can ameliorate the air pollution threats.

k. **Useful practices:** Practice of low sulphur/fossil fuel in electric utilities, less CFC and carbon-producing soil, and forest preservation. Using filters and scrubbers in motorised vehicles and factory chimneys.

l. **Health Aspects of Air pollution:** is to be stressed by Federal Institutions with Vehicular Pollution Control and Satellite-Based AQ Monitoring Systems with Environmental Damage Assessment

However, the AQI depletion during 2020 and 2021 was temporary, permanent long-term solutions are adapted to maintain the air quality pollutants at a prefixed standard to save humanity from future cataclysms. The highly polluted atmosphere causes respiratory origin diseases like ARI, COPD, UTRI, AFB, asthma influenza, bronchitis, etc. It may be considered to chalk out a plan and implement it through proper training, creating awareness and zero slum (SDG Target 11.1) and focusing on their health and habitations within Kolkata City [57].

4. CONCLUSION

The concentration of Respirable particulate matter (RPM) and NO2 in ambient air have

exceeded AQ national standards and the NAAQS. Kolkata's air has turned highly polluted alarming human health. Now it is to time analyse data from the local hospitals and health care units, particularly from economically backward and slum dwellers a health survey and the particular diseases that are affected due to air pollution, particularly respiratory manifested diseases. The investigation shall make a correlation between the pollutant parameters and the disease associated.

A massive awareness programme along with poor living conditions, less awareness on avoiding pollution, and lack of knowledge [58]. about pollution including diseases. Cooking inside the living room is a major issue which has been practised in the area of slums of Kolkata as shown in this study. Although the study has not set to assess the susceptibility of people to indoor pollution, it may inter the level of vulnerability the slum dwellers are exposed to indoor gases released due to domestic fuel exhaust. The holistic transformation of slum areas in the greater Kolkata city is warranted.

India Meteorological Department (IMD) has been assigned with the issue of bulletins about Air Quality and Weather forecasting both on micro-scale and mesoscale using the run of the AQ model SILAM for this purpose. The AQ Early Warning System (EWS) has been technologically developed under the sponsorship of the Ministry of Earth Sciences, IMD and Indian Institute of Tropical Meteorology (IITM), Pune. The government of India on the national level has established a Long-Term, Time-specific, strategy plan to challenge the major Air Pollution of PM2.5, NO_2 and PM10 concentration by Dec 2024 which must be adhered to.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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