Anthropocene Air Quality impact on theKolkata people

Abstract:

Health Research Institute reports Kolkata as the 2nd largest polluted but fast-growingmetropolis called the diesel capital,energy-guzzling, and mobility-rippled city.The present study is the correlation between Kolkata city during the pre-Anthropocene (1950s) and the concurrent air quality related to human health as a consequence of air pollution.

The study aims to portray the current air pollutants, causes, classification and measuring apparatuses recommended by the India Meteorological Department. The present level of Particulate Matter, CO, CO_2, NO2, O_3 and SO2, iscollected from WBPCB, and other institutions and analysed.

The results ofthe analysis show that air pollution is an increasing trend in the 21st century and vehicles are a major contributing factor. The critical level of air pollutants especially the particulate matter and NO2 in different parts of the city are fossil fuel.

Different zones in the city are residential, commercial and industrial areas, it is observeddifferent levels of pollution in each area. The second part of the study explored the seasonal variation of air pollutionand foundthe highest concentration during winter.Some suitable measures are thought of to mitigate the menace of air pollution to pave the way for bringing sustainable urban development to Greater Kolkata.

Keywords: -air pollution, airquality Index, health, population growth, Kolkata city.

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).The persistent pollutions that affect human health and disturb the life cycle 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 (Mishra et al., 2017[1], Davis 2023)]).The anthropogenic activities latercontinuously augmented the AQI and havean 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 projectedto cause 1,500 deaths/year anda fiscal loss thereof shall be USD 220 million. Kolkata (posthumous Calcutta) is a vast low land, now a cosmopolisthat stretches adjacent tothe Hooghly River and 1.5 and 9 m elevation. Thecity isamongthe four main metropolitan cities in India. Itis one of the cultural and commercial hubs of the British in India. Presently Kolkata citypossessesa yearlyaverage of 84g/m3 of fine particulate matter

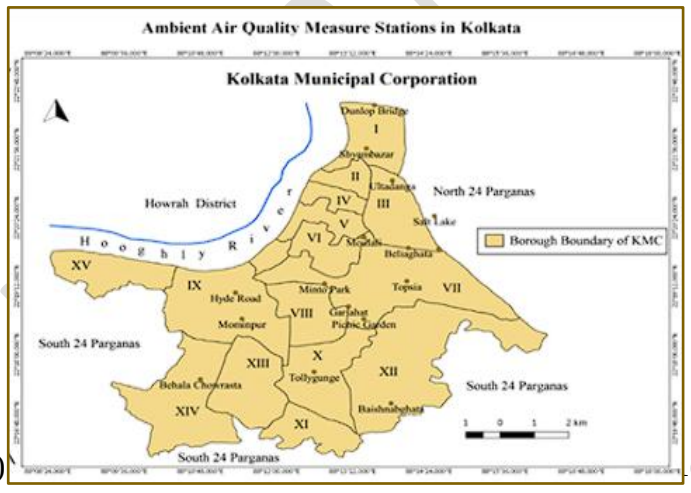
(PM2.5)whichis 17 times higher thanthe World Health Organisation's (WHO) safe limit and IMD reports.

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 cardiovasculardiseases amongthe 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 healthimpacts on comorbid people with lung/heart diseases,
0-50 Good / 51-100 Moderate / 101-200 Poor / 201-300 Unhealthy / 301-400 Severe / 401-500(+) Hazardous		

The Air Quality Index (AQ) refers to a tool, that reports daily air quality. Itsays about the cleanliness of air which is associated with the life of humans, flora and fauna living in the atmosphere. 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&b), Table1)

(a)



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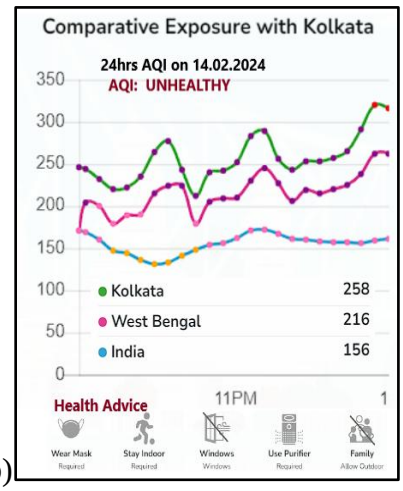


Fig 1 (a): The index map of the KMC Area, WB, (b). Kolkata AQwas unhealthy on 30th/31st Jan 2024, at Victoria, https://www.iqair.com/in-en/india/west-bengal/Kolkata)

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 theriver Hooghly (Ganga) of area KMC: 206.08 sq. km; The climate is humid insummer 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 wasmore than 4.5ml 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.**

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 µmdia. (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 thatpenetrate 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 SuspendedParticulatematter(thoracic fraction)(24 hrs)(µg/m3)	0 -50 (Good) 51-100 (Satisfactory) 101-250 (Moderate) 251-350 (Poor) 351-430 (Very Poor) 431 and + (Severe)	Formed by mechanical attrition of dust, lung deposition mainly by impaction, size 2.5 µm –10 µm arecoarse fractions. It causesasthma, bronchitis, and heart attacks. Long-term exposure to high concentrations leads to lung cancer, chronic respiratory illness/allergies
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. NOxformswith H_2O, O_2 and other chemicals. That causes*acid rain/haze*. Short-term/high-levelexposure causes asthma, coughing, wheezing or difficulty breathing,respiratory diseases, dyspnoea, broncho-spasm/ pulmonary oedema.
O3: Ozone (8 hours): ($\mu g/m^3$)	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, (8hrs) 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 fromstoves; 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); ($\mu g/m^3$)	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) ; ($\mu g/m^3$)	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 symptomslike Impaired memory, brain edema, Intracranial hypertension, Ataxia, coma etc.
Pb, Lead Metals	0 – 0.50 (Good)	Can cause Reproductive problems, High blood pressure,

dust; (µg/m3)	0.5- 1.0 (Satisfactory) 1.1-2.0 (Moderate) 10 –3.0 (Poor) 3.1 – 3.5 (very poor) 3.5 - + (Severe)	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 2019-20[3], Ohlwen et al, 2019[4], Kwon et al, 2020[6], Lu et al, 2023[6];

The present study is for the concurrent AQI of Kolkata City (Fig2(a) and the parameter-wise categorised (**Table-2**). The observatories to measure the AQI are taken at Victoria, Rabindra Bharati, Howrah, Haldia and Sidhu Kanhu indoor Stadium (https://aqicn.org/city/india/kolkata/us-consulate/). They estimate the quantum of particulate matter. Haque, 2017, conducted a study in 2017 about health-related diseases due to air pollution like COPD and other acute respiratory infections (ARI) caused by air quality. His findings are respiratory diseases (85.1%), and later fragmented it as ARI (60%), COPD, ((7.8%), upper track respiratory infection (UTRI) 1.2%, Influenza (12.7%), and AFBs (Acid fast bacillus) (3.4%), Haque MS. 2017[7]. The latest AQI with weather data is in **Fig 2(a and b)**

The AQI report analysed for the cosmopolitan city Kolkata in Oct 2023 from 2019 to 2023 observed that PM 2.5dropped during the years 2019- 2020 by 26.8% influenced by restricted mobility and closures. Later in the year 2021. The AQI raised 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,**

Table 3: Kolkata Real-time PM2.5, PM10 air pollution level West Bengal; Last Update**: 01 Feb 2024, 09:49pm(**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

Air pollution can be possible in the Cosmopolis due to the ever-increasing population, anthropogenic activities like land use,low thermal inversions, traffic and transportation problems, slums and settlements,policy of water supply, agricultural practices, drainage facilities, and waste disposal. 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 remains at its peak during the morning (6 AM) and later inthe evening 6(PM). And varies in the other periods of the day and night. It has been seen that Ballygunge remains always high among the Places (TOI, 8th Nov

2023[8]).There are 432 cars/kmon Kolkata's road on average, (ToI, 20th June2022[9]) West Bengal as on 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 Corporation (MNCs), LTD / PVT LTD / limited liability partnerships (LLPs)(World Biz in -2023[10]). For last three decades, the AQI has surged and turned apocalyptic, it warrants a thorough investigation of the air quality and needs study, Planning and redressal of its impact on Human health in Greater Kolkata.

The Britannica has reported that air pollution in Calcutta has triggered potentially inbetween the early 1950s and 20s of the 21st century. Calcutta in the 1950s, was usingwood, dung, and oil as fuel, releasing dark smoke through chimneys and trams, man-pulled rickshaws and horse-drivenvehicles 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.

(a)  (b) 

Fig 2:(a) Howrah Calcutta, Glenn Hensley, Photography (1944)(b) Traffic jam during Puja days 2023(ABP News Bureau Nov 2023[11])

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 (CO_2), air toxins, like Carbon Monoxide (CO), Hydrocarbon (HC), GHG gases, Nitrogen Oxide (NOx), and PMs of various sizes, Fig 3(a) & (b).

Review of Literature:

Air quality surgedeterioration has impactedhuman health for two to three decades as per Epidemiological investigations. A rise inconcentrations of ambient airparticulate 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. At timesthey become apocalypticpandemicslike H1N1 or COVID-19, (Lee et al, 2018[12], Manisalidis et al, 2020[13], Gautam et al, 2021[14]). TheHindu reported that only air

pollution in India caused2.18 million deaths/annum on 30th Nov 2023. Globally the number of premature deaths due to air pollution is4.8 million/per annum (World Health Organisation 2022[15]). Major cities in the globe including Kolkata live in an atmosphere with ambient Aerosol (PM2.5) concentrations exceeding the average concentration of 5µgram/cum (WHO-2022[15]). . the current WHO guideline for an annual average conc. of 5 µg m–3 (WHO, 2020, 2022). PM2.5 only causes4.2 million deaths and ~103.1 mil. disability-adjusted life-years (DALYs) globally (Lu et al, 2024[16]).

The pandemic, COVID-19 had hugehuman losses but as a boon improved the ever-deteriorating air quality of most megacities of the globe including Kolkata City, India. pen air waste burning, construction and roadactivity, dust, firewood, vehicular exhausts, thermal power generation,Diesel generator sets, and industrial blast furnace fumes. There is a relationshipbetween air quality with meteorological parameters like temperature, wavefronts, rainfall, humidity etc., (Kelly et al, 2015[17], Bera et al 2020[18], Kabiraj et al, 2020[19],Duttaet al, 2024[20]).

The vulnerable groups are the infants, paediatrics, geriatrics, comorbidand urban masses are mostvulnerable to health impacts due to high AQI(Chen et al., 2008[21], Filippelli et al., 2020[22], Pande et al., 2021[23], Dutta et al., 2021[24], Barua et al., 2023[25]).. During the pandemic, SARSE Covid-19 impositions (Mar 24th –May 31st, 2020)there wasa depletion in AQIin an average was 53.61%, (Kabiraj et al, 2020[19], Sarmadi et al, 2021[26], CSTEP 2022[27],Choudhury 2024[28]). Indoor air pollution (IAP) can be checked by potential pollutants likeDG sets, cattle sheds, cooking, and agricultural waste burning.

The IAP hasemerged as a major alarm for all countries due to itsdisastrous impact on mortality and morbidityin urban rather than rural areas, (Saini et al, 2020[29]). The literature review infers that there areextremely high levels of pollution in Kolkata city. Being a very old city (of 2000 YBP), it became important after 1717. Warren Hastings shifted all its administrative offices to present poorly planned 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 theair quality level at a safe limit. So, the various parameters that cause air pollution in Kolkata are to planned for our future generation.

The Objective,

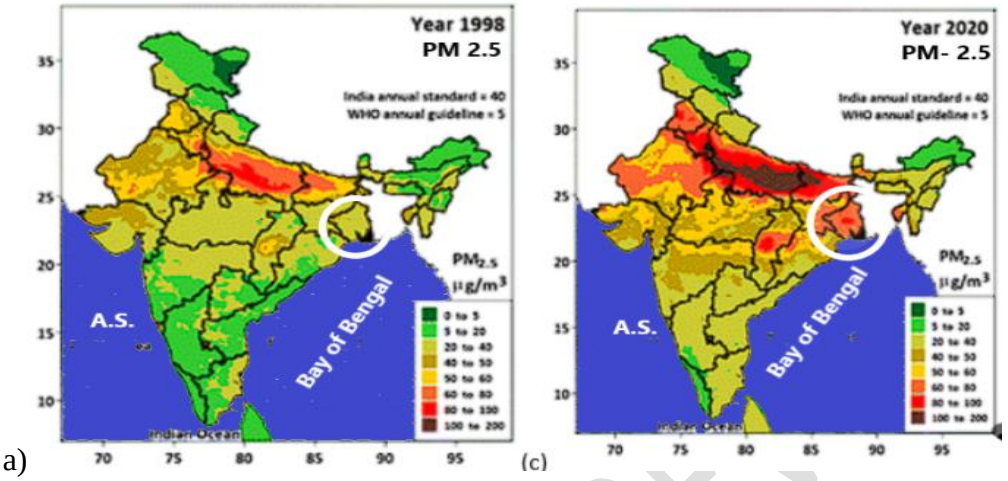
The study aims to find out the actual conditions of air pollution and air quality of Kolkata and also find out different types of measures taken to control the pollution.The objective of the study is:

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

Methodology:

Air pollution constitutes Ambient air pollution and Householdair pollution. The prime bases of anthropogenicair pollution are fossil fuel emissions, specks of dust from traffic,

construction sectors, manufacturing, power generation and chemical units.The areas responsibleare 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.



a) (c)

Fig:3–(a) Kolkata Municipal Corporation (KMC) showing ttheThe air quality index changes from 1998 to 2020 (source: Guttikunda et al 2022[30], modified)

The Central Pollution Control Board (CPCB) Govt of India (GOI) through a National Air Quality Monitoring Program through NAQMP observesair quality data like PM2.5, PM10, and NO $_2$, SO_2monitored 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 (https://app.cpcbccr.com/ccr/) and, https://aqicn.org/city/india/kolkata/victoria/

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

The ambient air quality data in Kolkata is observed by the WBPCB, the Central Pollution Control Board (CPCB), by 17 monitoring stations, analysedand compared the average value with the NAAQS standard and published on its website,**Fig 3**). CPCB categorise them as low, moderate, high and critical. The raw data needs conversion to an air quality index (AQI) and analysed to get the AQI and correlated with the human impact on Kolkata.

Table 4: The principle and instruments used formeasuring air pollutants, (Source:CSTEP. (2022)[27].IMD EMRC (SOP) 2021[31]

Source Emission	Symbols used for	Formulae used	Instrument used by IMD at Delhi(Tool Kit)

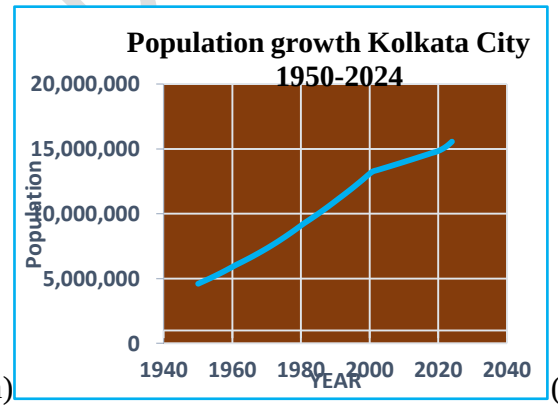
Transportation (PM 2.5/ PM 10/ NO_x/ SO_X)	$VKT_{ij}: Vehicletravel\ \frac{km}{day}: RL = roadlength;$ E = total emission; $n = Nosectoralunit:$ EF= Emission Factor(action wise)	$VKT_{ij} = RL_j * n_i$ $E_j = EF_i$	Continuous Ambient Particulate Monitor (SPM) PM10/PM2.5 head (Model FH 62 C14 Series); 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 SystemMagee 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	$E = VKT * EFEF_{roaddust} = [k * sL^{0.091} * W^{1.02}]$	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 (Model49i-B-3-N-C-A);

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 ofNER, Tripura, Odisha and Bihar. 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, (the 2011 census). As Kolkata Municipal Authority (KMA) comprising of KMC and its suburbsaccommodates 15.57 million people, (a population growth rate of 1.55%, in 2024),Dataful.comwww.census2011.co.in/census/metropolitan/184-Kolkata).(Fig 5(a&(b)

Kolkata is the dusty city, whose. air pollution becomes acute during winter when pollutions range higher than at other times. The worst polluted traffic intersections double the city's average pollutants in busy hourswww.macrotrends.net/cities/21211/calcutta/population.

(a)



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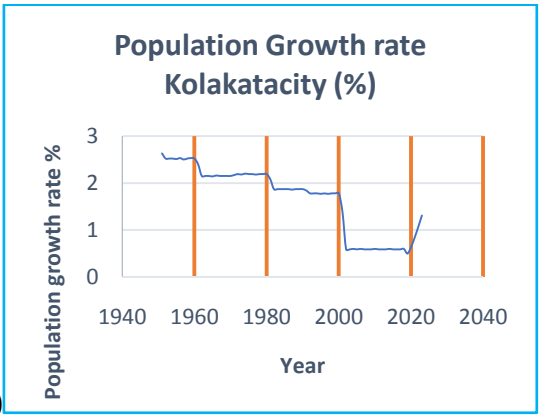


Fig 5(a &b): Thepopulation Kolacota (a) Population wise (b) the growth rate wise

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: Other parameters observed in Kolkata City that affect air pollution.

Parameter s	Sources	Receptor	Human Impact
VOCs/ VVOCs / SVOCS:very/SemiVolatilevolatileorganic 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 damageliver, 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%, radon level
Biological Allergens	Animal excreata, cat saliva, house dust, mites,cockroach, and pollen& microorganisms	Inhaling, contact	Sensitization, respiratory infections, respiratory allergic and wheezing
Building-related illness (BRIs)	Exposure to inorganic, organic,	inhalation,	Irritation of eye

	physical, and biological contaminants,	ingestion, or dermal contact,	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, 2014[32], Seltzer et al, 1994[33], .USEPA 2020[34], Tran et al.,2020[35], WHO'sHandbook 2009,[36]Gerardi et al, 2010[37], Shilpa et al, 2023[38].

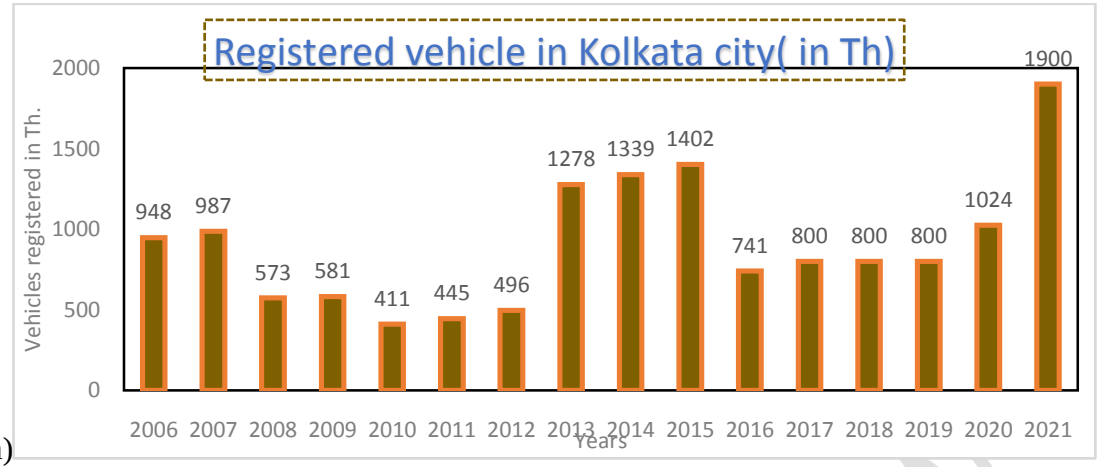
Major causes of air Pollution in Kolkata

The main causes of high air pollution in Kolkata aremeteorological, transportation, solid waste burning, domestic fuel for cooking, Industries, DG sets, construction and aviation etc. Air pollution in Kolkata is due totransportation (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. Inthe 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 (Economic Times, 2023[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 (TOI, Ghosh D, 2023[40], NCRB record, 2022[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, (NCRB Report 2022[41]).In ranking it is in 16th position, yet most of the fatalities are due to bad climate and visibility (IMD report 2021).

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 (Bandopadhyay, K 2023[43]).

5(a)



5(b)

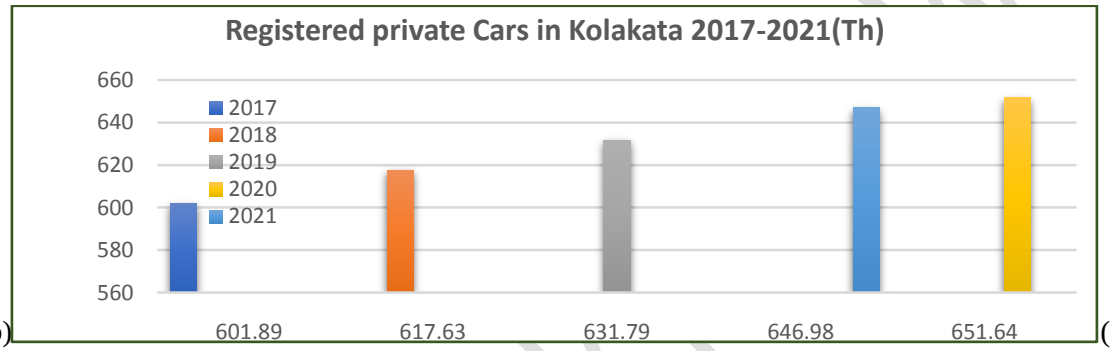


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Fig 6(a): The number of vehicles registered (2006-2021); Fig 6 (b)Registered Private cars **in Kolkata**

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. The city is situated along 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 WestBengal Pollution Control Board (WBPCB), under NAMP,is monitoringthe ambient air quality of major urban towns and industrial areas of the statein the district of Kolkatafor 17 stations daily two times to have 104 observations/year.

Meteorological air quality changes:

A recent analysis of air quality data shows that as per the national air quality index (NAQI) followed in India the ambient air quality index of Kolkata remains "poor or very poor or severe "categoryfrom 18 to 20 days in winter being influenced by meteorological events.The PMand $NO_2$are the causes for the attainment of the severe pollutantcategory. On 8.10.2018, the air quality exceeded the national ambient air quality standards (NAAQS) for Kolkata. Which was a case of air pollution 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.

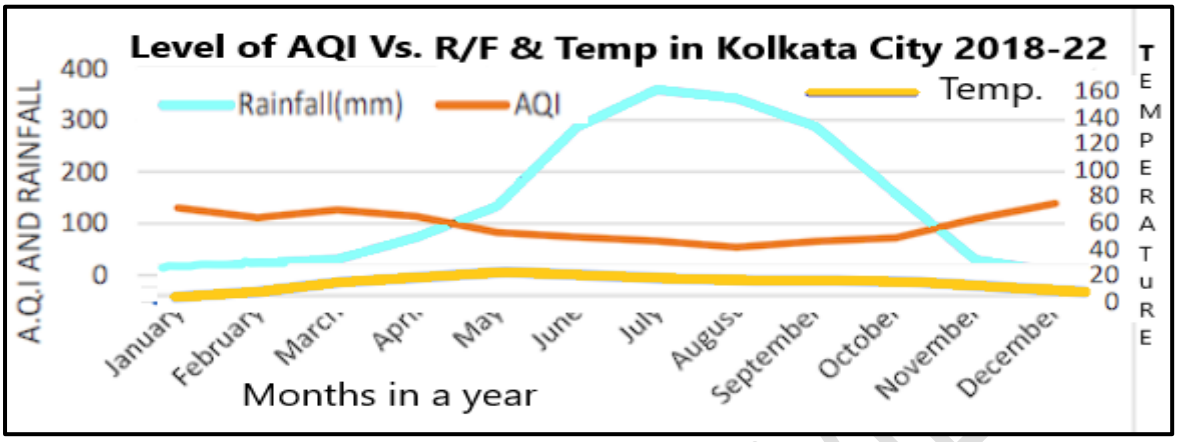
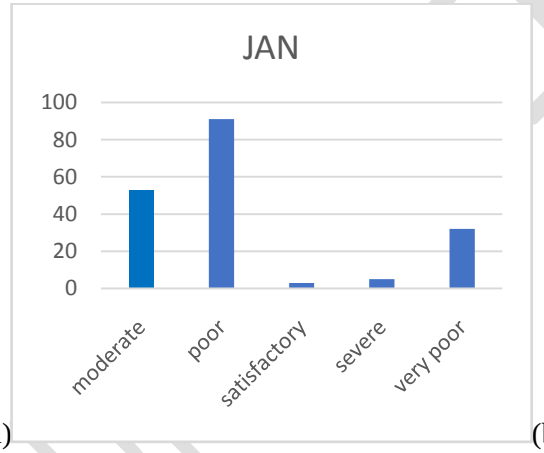


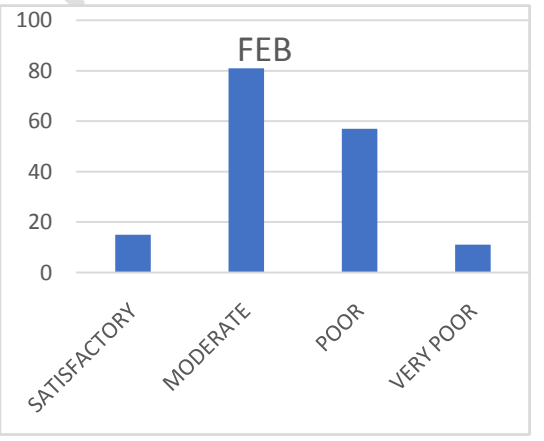
Fig 7: Relation between AQI and meteorological (R/F&Temp)Kolkata city (Source: Dutta A et al 2024 modified[20])

Air Qualitymonthliesin Kolkata (2015-2023)

AQI level in Kolkata May 2015 to 12November2023) has been taken and the variation in quality is given 6(a-l).



(a)



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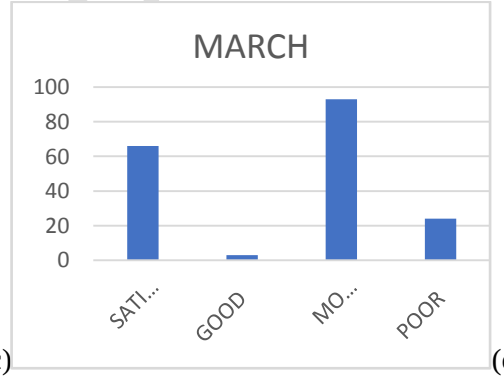

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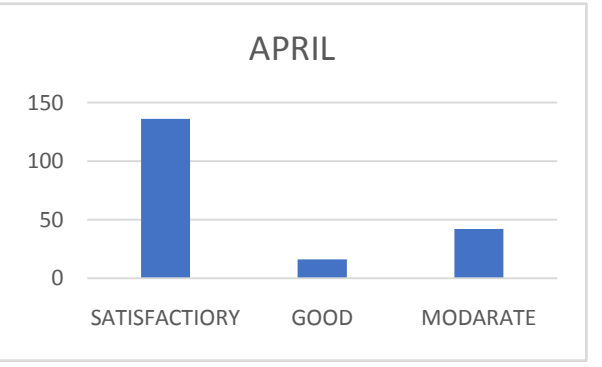


(d)

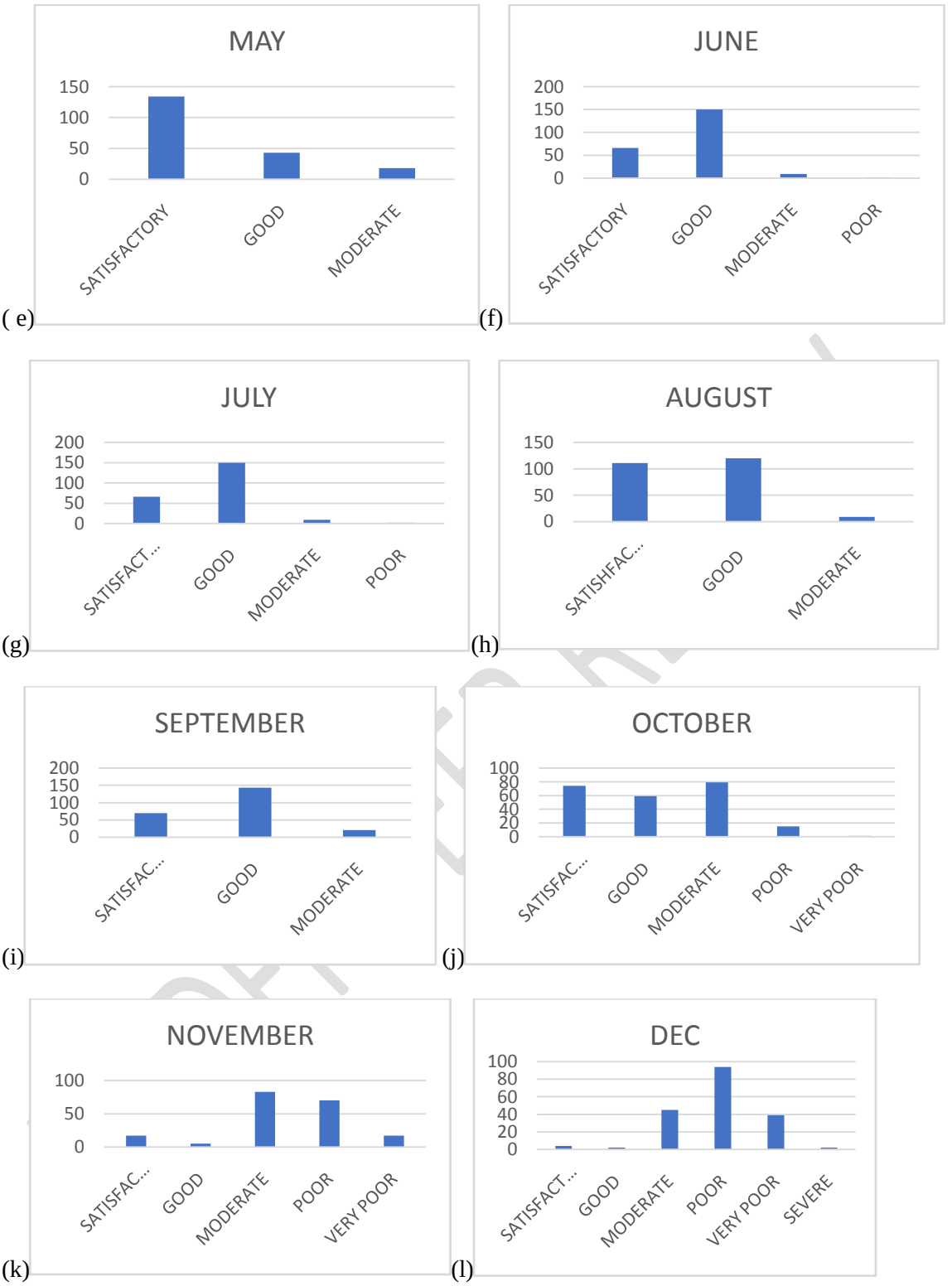


Fig 8(a-l): The AQ month-wise from May 2015 to 12 Nov 2023 (source: Dataful)

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.*

Meteorology events and air quality in Kolkata:

The EMRC (EnvironmentMonitoring and Research Centre), IMD, . EMRC observes the atmospheric air quality constituents that change theclimate 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 reducepollution concentrations. In the winter there exists a lowering of temperatures and inversion that has more impacton emissions. Low temperatures also increase emissions due to the burning of husks and warming (IMD 2021[42],Kuttippurath.et al, 2023[44])

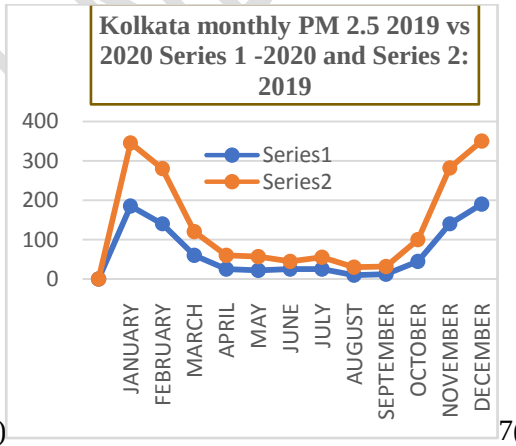
Respirable particulate matter:

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

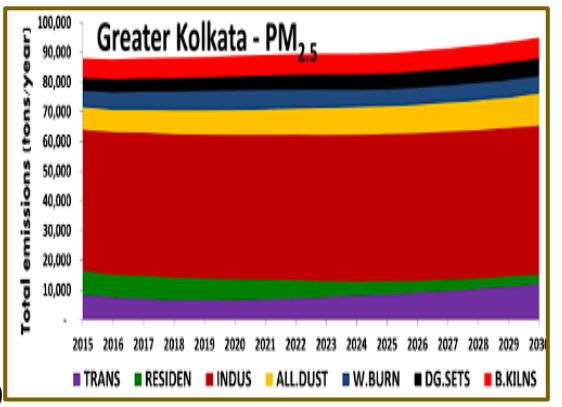
Interpreting health outcome of surveyed dispensary inKolkata:

There are more than 25 major dispensaries and many more minor dispensaries, operating throughout Kolkata. A health survey has been conducted at dispensaries owned by Kolkata Municipal Corporation (KMC) in Kolkata, considering criteria like easy accessibility and availability of target cases. The main purpose is a major challenge for healthy living and not to be misinterpreted as a correlation between air pollution and health.

It is observed that the short-term health impact due to RPMs is the estimated number of attributable cases (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, (Ghosh et al., 2024[45]).



7(a)



7(b)

Fig9(a &b): The AQI of Kolkata city for PM 2.5 (2019 and 2020)and projected PM 2.5 upto 2030. (Source: AQ for Kolkata (Calcutta), India, https://urbanemissions.info/india-apna/kolkata-india/)

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.

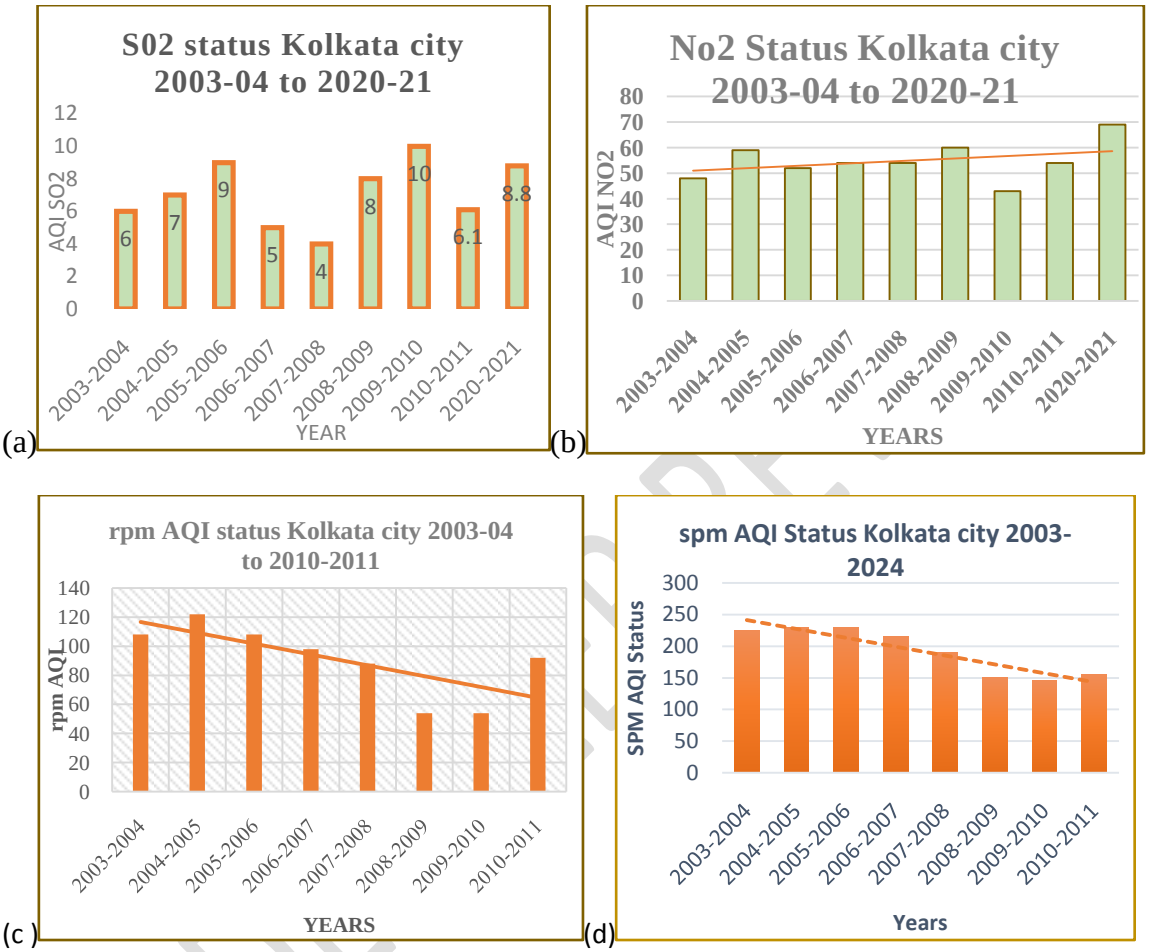


Fig 10 (a-d) the trend in parameters that affect the air quality of Kolkata city

The respirable particulate matter and the suspended particulate matter has a decline trend during 2000-2011 i.e. the first decade of the 21st century.

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. 7 (a) & 7(b)

Diseases analysis: -

The dispensaries Behala and Tangra dispensaries have recorded more than 90% of the respondents withrespiratorydiseases. while Ultadanga dispensary has recorded 71.4%.in Ultadangadispensary, 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.

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 withpollutant data. SO_2, CO, NO_2, and NH_3, exhibited drastic variation.Bera et al, 2021[46]. 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.

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. 40µg/ cum for five to six months/year (particularly in 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.

Discussion:

The concentration of RPM and NO_2 in the ambientNational 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 PM2.5to surge as per the West Bengal Pollution Control Board (Bandyopadhyay K. 2024[47]) due to strong westerly wind causing heavy fog (haze of smog) blanketing the city and raising COPD cases.

Health Impact:

SARS COVID-19 has shattered the life of Kolkata due to the shutting of Industries, transport, education, and socialconnections, (enforcing strict quarantine, Lockdowns, social distancing, and closingeconomic 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, (Biswas et al, 2022[48], Kar et al, 2024[49]).

PM10 and NO2 were recorded around the KasipurCossipore thermal power station. As per World Bank blogs In India, air quality has been improving despite the COVID-19 lockdown (Narayan et al 2020[50]).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, in addition, they also generate pollution due to occupants' activities. Biomass smoke, cooking, stoves, diesel generators, various electronic gadgets, smoking, paints, chemicals, etc and they increase Carbon monoxide (CO), aerosol, particulate matter (PM), and volatile organic compounds (VOCs). , biological pollutants, and others. So the pollution in Kolkata makesits inhabitants of slum areas suffer from COPD, ARI and other respiratory diseases., (Tran et al., 2020[35]).

One can protect oneself ifthe 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 surgingin winter(Nov to March) whereas the. PM2.5 levels started rising in October.With more shanty towns underpoor dwellingconditions,more awareness to be created toavoid air pollution. The shared kitchen withinthe living room is commonin slums and is the major cause of indoor pollution, (Haque et al, 2017[51], Mishra et al, 2020[52], Das et al., 2021[53]).

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 (Mishra et al, 2020[54]).

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.

Various contributorstodeclinedAQI areenvironmental, socio-economic, anthropogenicetc. There is a need for attentiontointerpreting the factors that cause a decline in respiratory health, stresses on large observation points, collection and analysis of data and further research to highlight new fields to be taken care of for managing the surge of air

pollution in greater Kolkata. The doctors come forward to give standing to the spateof 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. Theo integrated to resettle the marginalized communities to bring these communities to the mainstream of the city.

The present study is a holistic transformation of slum areas, developing like wild mushrooms in the greater Kolkata city, which should take care of the transformation of shanty townswith minimum WASH standards. The diseases caused onaccount 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 createa 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, candeliver solutions to ameliorate the impacts of multipollutanton greater Kolkata air quality

Suggestive measures forhealth issuesin Kolkata city to reduce AQI

Understanding the local air quality causatives and their impact onhuman healthand their susceptibility to Kolkatacosmopolis by reducing pollutants like carbon and CFCs, (SDG-3), Ghosh et al, 2020[54],https://www.biomedcentral.com/collections/apah.

Measures for various sectors:

a. **For the transportation sector**: Substituting or retrofitting existingbuses withdiesel particulate filters DPCs and allpetrol and diesel vehicles to run with either CNG or electric and ban on petrol and diesel vehicles. Use offilters and scrubbers in cars and factories chimneys to enhance air pollutants.Office-goingstaff should avoid personal automobiles and use public transportation, common pull or carpooling.
b. **From domestic sector pollution**, stopping use ofsolid fuel and increase of LPG connections for cooking and use ofinverters in place of diesel/petroldriven 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 and vertical expansion has become almost impossible. Old built-upshave been ruined and are being rebuilt multi-storied as vertical expansion coping with the population rise with innovations. The dusts generated during dilapidation and construction generate huge amounts of air pollutants, Strict legal enforcement of

current guidelines on pavement and building construction need to be followed to reduce these pollutants along with disposal.

e. **DG sets operation:** ban all DG sets on sale and operation within the city.
f. **Regular monitoring**to develop measures and/or evaluating, analysingexposure savingapproaches and recording for future policy making.
g. **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.
h. **Carbon credit/ carbon tax:** Practices of benign nature-basedcarbon 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.
i. **Useful practices:**Practice of low sulphur/fossilfuel in electric utilities, less CFC and carbon-producing soil, and forest preservation. Usingfilters and scrubbers in motorised vehicles and factory chimneys.
j. **Health Aspects of Air pollution**are to be stressed by federal Institutions with Vehicular Pollution Control and Satellite-BasedAQ Monitoring Systems with Environmental Damage Assessment

However, the AQI depletion during 2020 and 2021 wastemporary, 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 atmospherecauses 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 (Mishra et al., 2019[55].

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 turnedhighly 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. 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 forecastingboth 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 planto challengethemajor Air Pollution of PM2.5, $NO_2$and PM10 concentration by Dec 2024 which must be adhered..

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