

Air Quality Scenario of the World's Most Polluted City Kanpur: A Case Study



Sarah Khan and Quamrul Hassan

Abstract Rapid industrialization and urbanization are paving a way for emerging economies to become more advanced, but these activities also trigger environmental problems. Among many of these problems, the biggest and the most persistent is the air pollution. According to the WHO database, Indian cities are leading the list of world's most polluted cities, with 14 of the 15 cities featuring in the list are Indians, which has been declared badly affected due to air pollution, and the worst among them is Kanpur. Years of studies and research have recognized the industrial sector as mainly responsible for polluting the city. As reported by Indian Institute of Technology, Kanpur, during winter months, the major contributor to air pollution is particulate matter like dust and soot accounting for around 76%, 15% has been contributed by biomass burning and about 8% by emissions from vehicle, whereas, in summer season, the percentage contribution of particulate matter came down to 35% with equal contribution from vehicular emissions. Meteorological data reveals that 20–80% part of the day mostly during winter months, the average wind speed remains between 2 and 4 m/s. This shows that the dispersion of pollutants in the winter season is very less, trapping particulates and toxic metals in the atmosphere to remain persistent for months. The exposure to these pollutants resulted in harmful diseases linked to the cardiovascular system, respiratory systems, nervous system, premature birth, mortality, and illness. Various efforts have been initiated by the authorities to control the increasing level of pollution, like constructing new roads and pavements, mass rapid transit service to cut car pollution, planting more trees and promoting battery-operated transport. The Ministry of Environment, Forest and Climate Change is also making a budgetary allocation of about 7 billion rupees (\$104 million) for installing more systems to monitor air quality in cities and installing equipment to settle the dust like water sprinklers. Despite all these efforts, the Air Quality Index of the city has remained much below the national average. In this scenario, this paper focuses on the studies made so far associated with the causes, sources, impacts, and outcomes related to air pollution levels in the city from the available literature. This paper has

S. Khan (✉) · Q. Hassan
Jamia Millia Islamia University, New Delhi, India

© Springer Nature Singapore Pte Ltd. 2020
S. Ahmed et al. (eds.), *Smart Cities—Opportunities and Challenges*,
Lecture Notes in Civil Engineering 58,
https://doi.org/10.1007/978-981-15-2545-2_57

693

also highlighted the air pollution scenario of neighboring country China and its policies intervention in battling against a similar situation.

Keyword Air pollution · Air quality · Particulate matter · Air pollutant

1 Introduction

Water and air, the two essential elements of life on which all life forms depend, have become the dumping grounds for all kinds of wastes. The basic minimum requirement to live a healthy life is to breathe clean air, which has now become difficult to achieve. Rapid industrialization, technological advancement, and urbanization have provided us better living standards but at the cost of damaging the natural resources which are the building blocks for the sustenance of life. There has been an upsurge in the concentration level of various gaseous pollutants and particulate matter (PM) due to widespread anthropogenic activities of various kinds. The pollutants which release directly from the source are termed as a primary pollutant, and these primary pollutants result in the formation of new pollutants due to the chemical reaction among them, called the secondary pollutants. These are building up in the atmosphere creating environmental hazards and affecting health globally. A report published by the World Health Organization (WHO) specifies that some seven million people have died in 2016 due to the increasing level of pollutants in the atmosphere [1]. Each year WHO releases list of world most polluted cities to bring the attention of global communities to take some actions, but little or no effort was made to improve the air quality. This year, WHO ranked 14 Indian cities in the list of 15 most polluted cities worldwide with Kanpur being the most affected based on data recorded in 2016 for PM_{2.5} levels [2]. The parameters adopted for selecting the cities were particulate matter PM₁₀ and PM_{2.5}. Particulate matter with size less than 2.5 μm (PM_{2.5}) is highly dangerous, penetrating deep into the lungs or cardiovascular system. The recorded level of PM_{2.5} in Kanpur was between 120 and 150, as compared to the WHO safe limit of 25. Air pollution is a global concern. Every country must monitor air pollution concentration levels at regular intervals. Quantifying air quality is a composite phenomenon, however, there are some pollutants whose effect on air quality is highly significant, and these include particulate matter (PM), nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) [3]. For measuring the pollutant concentrations, National Ambient Air Quality Monitoring Programme (NAMP) has been initiated by Central Pollution Control Board (CPCB) in 1984–1985. Under this Plan, 342 stations for monitoring air quality were set up in 127 Indian cities [4], and National Ambient Air Quality Standards have been formulated as a measure of comparison, to ascertain that the concentration level of pollutants does not exceed these standards at any location. Based on the National Air Monitoring Programme (NAMP), the air quality is categorized under four broad categories based on the exceedance factor. The categories are critical (*C*), high pollution (*H*), moderate pollution (*M*) and low

Table 1 Air quality categories based on NAMP

Pollution level	Annual mean concentration range ($\mu\text{g}/\text{m}^3$)					
	Industrial, residential, rural and other areas			Ecologically sensitive area		
	SO ₂	NO ₂	PM10	SO ₂	NO ₂	PM10
Low (<i>L</i>)	0–25	0–20	0–30	0–10	0–15	0–30
Moderate (<i>M</i>)	26–50	21–40	31–60	11–20	16–30	31–60
High (<i>H</i>)	51–75	41–60	61–90	21–30	31–45	61–90
Critical (<i>C</i>)	>75	>60	>90	>30	>45	>90

Note Table is taken from importance of national ambient air quality standards, by Anushua, published in Green Clean Guide dated 24 January 2016 [5]

pollution, with exceedance factor for *C* level are greater than 1.5 and *L* level less than 0.5 [5] (Table 1).

2 Study Area

Kanpur is the major industrial centre of North India, situated on the banks of river Ganga, with its own historical, religious and commercial importance. It has been popularized by the sobriquet “Manchester of East” and “Leather city of the world” as it is the hub of the textile and leather industry in the region.

2.1 Geographical Aspects and Sources of Pollution

According to the 2011 census, Kanpur serves 2.7 million people growing at the rate of 2.47% annually with 6800 persons living per square km. The city is divided into urban area spread over 322.84 km² and rural area 2832.16 km² [6]. The city is surrounded by two rivers, the Ganges encircling the north and the river Pandu flowing south. The city follows rivers and the railway lines linearly. The centre of the city is occupied by various industries such as heavy engineering, tanneries, textile, leather, and fertilizers. The key sources of air pollution are emissions from industries, vehicular emissions, dust from the road and domestic cooking. Air pollution in the industrial and residential areas of the city remains 5–6 times above the National Ambient Air Quality Standards [5].

2.2 Meteorological Aspects

The city is situated at an average height of 128 metres above the mean sea level, between 26.47° N latitude and 80.35° E 137 m longitude. The climate of the city

lies in the range of humid subtropical region having a characteristic cool dry winter and comparatively hotter summer. The maximum temperature recorded in summer is about 44 °C and the minimum temperature dropping to nearly 0 °C in winter. The annual precipitation level is about 820 mm received mostly in the monsoon season between June and September. The meteorological data based on the climatic pattern has been prepared using meteoblue climate diagrams show that maximum rainfall occurs during July and August, while the temperature remains high during May and June. The diagrams have been prepared by using data over 30 years also show that wind speed remains between 12 and 28 m/s throughout the year [7].

3 Air Quality Monitoring and Pollution Status

The activities responsible for rampant pollution level in the city are as follows:

1. Transportation sector mainly private diesel tempos and buses contribute to the vehicular emission.
2. Commercial activities comprise diesel/kerosene generators frequently used during power cuts.
3. Industrial activities, the major being thermal power plant, textile industries, leather industry, tanneries among other sources.
4. Domestic activities, institutional and official activities.
5. Miscellaneous sources like dust emission from poorly maintained and partially paved roads.

As per a report by IIT, Kanpur (2010) report, during winter months, the major contributor to air pollution is particulate matter like dust and soot accounting for around 76, 15% has been contributed by biomass burning and about 8% by emissions from vehicle, whereas, in summer season, the percentage contribution of particulate matter came down to 35% with equal contribution from vehicular emissions [8].

Air Pollution Knowledge Assessment City Program (2015) has created a source-wise percentage share of particulate matter with size less than 2.5 μm , as shown in Fig. 1 [9]. Various studies have been conducted on monitoring, emission inventory, seasonal variation, assessment and apportionment study as available from literary sources, and one of the studies includes a project which had conducted regular air quality sampling and analysis of PM₁₀, SO₂ and NO₂ at Vikash Nagar, Kanpur, which had generated air quality data for the period 2005–2007. The study yielded that the PM₁₀ level ranges from 50 to 600 $\mu\text{g}/\text{m}^3$, and PM_{2.5} levels are 25–200 $\mu\text{g}/\text{m}^3$. The data for NO_x and PM₁₀ does not co-relate, and this indicates PM₁₀ is contributed by other sources also, apart from combustion. TSPM and PM₁₀ link to the same source. The winter months recorded the worst level both for PM₁₀ and NO₂, and monsoon season recorded the satisfactory level both for PM₁₀ and NO₂ [10]. The study carried out by New Delhi-based SIM Air (air pollution

research and modeling body) considered private vehicles in Kanpur responsible for the high level of CO₂ emissions (84%). Another study has compiled the composite index of air quality. The major contribution (more than 90%) for the index is from particulate matter. Air Quality Index has been prepared for the seven sampling locations based on the land use pattern. This study has determined that during cold months, air quality remains bad. The same has been reported for March, April and early parts of May. During this dry season, winds blow carrying road dust ensuing high SPM. Air quality then advances during the rainy season and after that [11].

One of the studies has been conducted at urban locations during June 2009 to May 2013 on long-term near-surface measurements of atmospheric pollutants reporting that the mean concentrations of sulfur dioxides were 3.0 ppb, oxides of nitrogen were 5.7 ppb, carbon monoxide level was 721 ppb, and ozone level was 27.9 ppb over the period. The winter months were under the cover of SO₂, NO_x and CO, released by various anthropogenic sources like vehicles, domestic cooking, bricks manufacturing, thermal power plants, stable burning which remain persistent due to low dispersion, whereas O₃ concentration touched high during summer season [12].

Air quality assessment, emissions inventory and source apportionment studies for Kanpur City, conducted by the Indian Institute of Technology, Kanpur (2010), have divided air quality monitoring stations based on predominant land use patterns. The predominant pollutants analyzed were suspended particulate matter, sulfur dioxide, oxides of nitrogen, carbon monoxides, organic carbon, ions, elements, volatile organic compounds. The conclusion drawn from this study again pointed particulate matter as the main culprit where the levels were 2.5–3.5 times higher than the standards. There was an abundance of soil particles like Si, Fe, Ca, Na, indicating the cause of pollution may be road dust. For NO₂, 50–70% contribution is from vehicles [10].

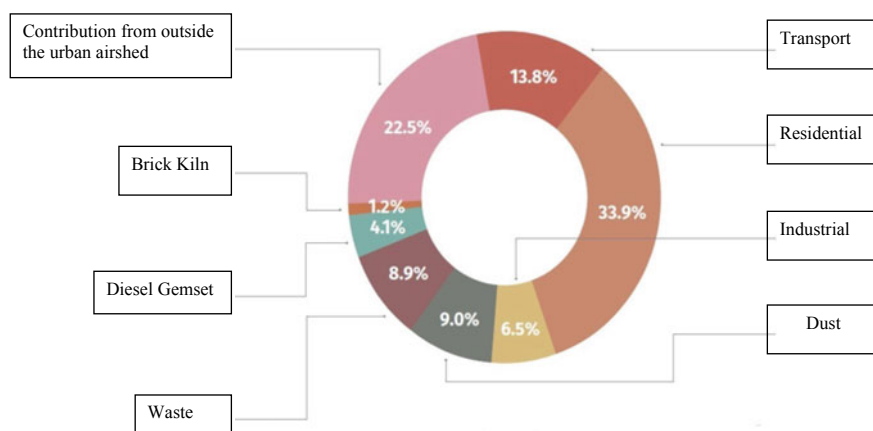


Fig. 1 PM_{2.5} concentration: source-wise percentage share in 2015. *Source* The Air Pollution Knowledge Assessment (APnA) city program report, 2015

A recent study conducted by urban emission info in 2015 shows that the monitoring at various locations in Kanpur is done under National Ambient Monitoring Program (NAMP), functioned under Central Pollution Control Board (CPCB, New Delhi), with one continuous air monitoring station (CAMS) and eight manual stations. The CMS monitors all the criteria pollutants, while manual stations record data on PM₁₀, SO₂ and NO₂ [2]. PM_{2.5} was determined using satellite data derived concentration. The resultant concentration for PM₁₀ has been reported for the year 2002–2014, shows that the trend in PM₁₀ level has remained on the higher side of the Annual Indian Standard (60 $\mu\text{g}/\text{m}^3$). From 2004 to 2008, the range of maximum concentration level was 305–532 $\mu\text{g}/\text{m}^3$, from 2008 to 2010, the range goes little down from 250 to 208 $\mu\text{g}/\text{m}^3$, and from 2010 to 2015, the level remains mostly on the higher side with maximum reporting up to 717 $\mu\text{g}/\text{m}^3$. The data for SO₂ shows that from 2000 to 2010, the level remains below the Annual Indian Standard (50 $\mu\text{g}/\text{m}^3$), and after 2010, there was a sudden rise in level with maximum touching 85 $\mu\text{g}/\text{m}^3$. For NO₂ concentration, the trend follows the same pattern as SO₂ with level remains in sync with Annual Indian Standard (40 $\mu\text{g}/\text{m}^3$), while after 2010, the maximum recorded level is 106 $\mu\text{g}/\text{m}^3$ after 2014. Concentration based on satellite feeds and global chemical transport models shows Annual PM_{2.5} concentration varies from 80 $\mu\text{g}/\text{m}^3$ in 1998 fluctuating in between to reach the highest level in 2004 of 100 $\mu\text{g}/\text{m}^3$, after 2004, the trend declines to be recorded as 85 $\mu\text{g}/\text{m}^3$ in 2014, and the National Standard has been given 40 $\mu\text{g}/\text{m}^3$ and WHO standard as 20 $\mu\text{g}/\text{m}^3$. The study has also prepared an emissions inventory for SO₂, NO_x, CO, Non-methane Volatile Organic Compounds (NMVOCs), CO₂ and particulate matter, for the year 2015 and also predicted the levels up to 2030. For the year 2015, the total emission in tons/year from all the sources combined was approx. 35,000 and is been estimated for the year 2030 to be 40,000 tons/year approx. [2].

4 Air Quality Trends

India has a vast network of monitoring stations designed to gather data on air quality. The system consists of 731 functioning stations spreading across 312 cities/towns in the country, monitoring four major air pollutants—SO₂, NO₂, respirable suspended particulate matter and fine particulate matter [13]. There are eight manual monitoring stations currently operating under NAMP in Kanpur at the locations as shown in Table 2 [14].

The air quality trend for the three major pollutants, PM₁₀, SO₂ and, NO₂ obtained for the past ten years has been compiled from various literary sources and presented in this study.

Figure 2 shows the previous ten years data of particulate matter taking an average of the concentration recorded over the eight monitoring stations. The trend line shows that the PM₁₀ level remains high over the ten-year period despite taking corrective measure [13].

Table 2 Air quality monitoring station in Kanpur

Sr. No.	Monitoring stations	Description of site
1	Forest & Training Centre, Kidwai Nagar	Residential
2	Chamber of Commerce Darshanpurwa	Commercial
3	Fazalganj, Panki	Industrial
4	Dabauli/Shastri NGR	Residential
5	Jajmau/Awas Vikas	Residential
6	I.I.T. Campus	Residential
7	Dada Nagar	Residential
8	Ramadevi	Commercial

Source ENVIS Centre: Uttar Pradesh status of environment and related issues

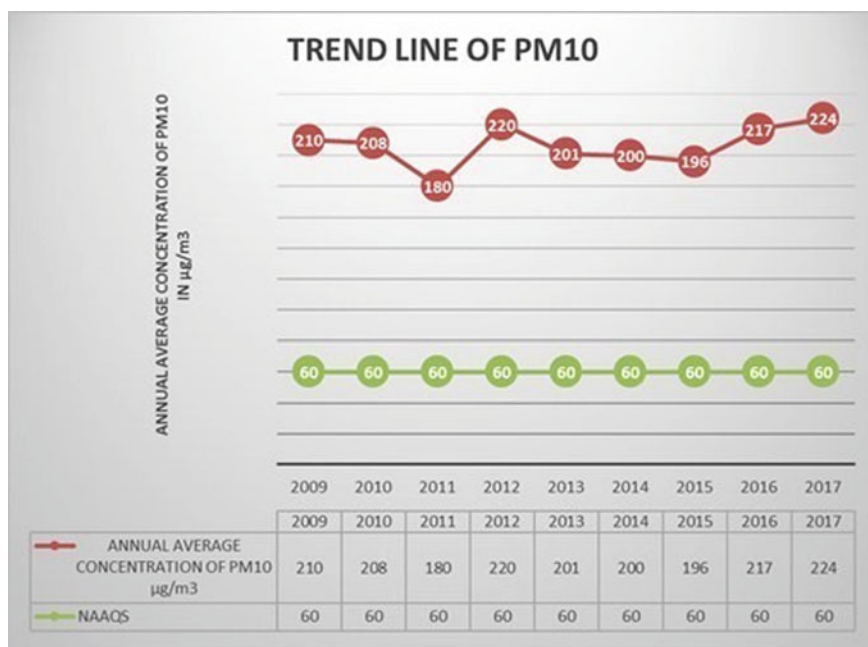


Fig. 2 Annual average concentration of PM10 for the years 2009–2017. Source CPCB-ambient air quality data for the year-wise

The trend in SO₂ concentration maintains a low profile and remains well below the national average throughout the past ten years [13]. The falling trend has been resulted due to policy interventions like decreasing the percentage of sulfur in diesel, use of CNG in automobiles, use of LPG as domestic fuel, etc. [15].

The trend in NO₂ concentration has maintained a steady rate over the years with a slight increase in the last two years [13]. This may be due to the stringent measure adopted in terms of vehicular emission and fuel quality.

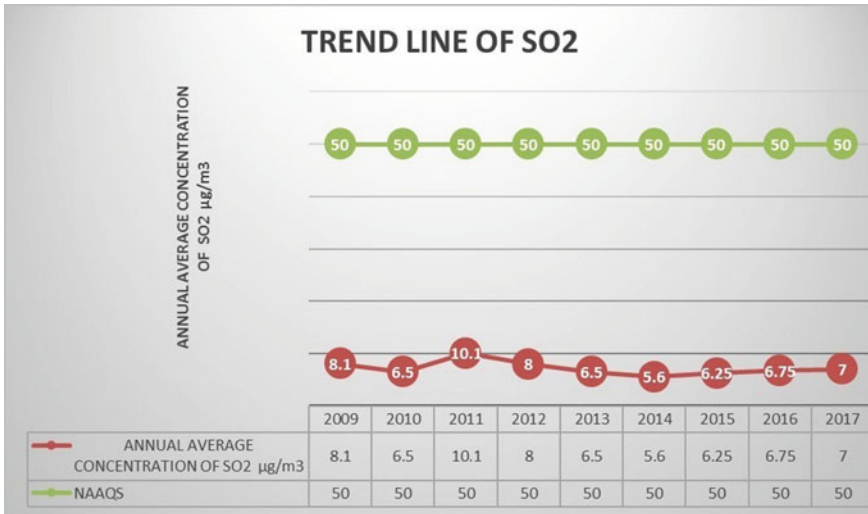


Fig. 3 Annual average concentration of SO₂ for the years 2009–2017. *Source* CPCB-ambient air quality data for the year-wise

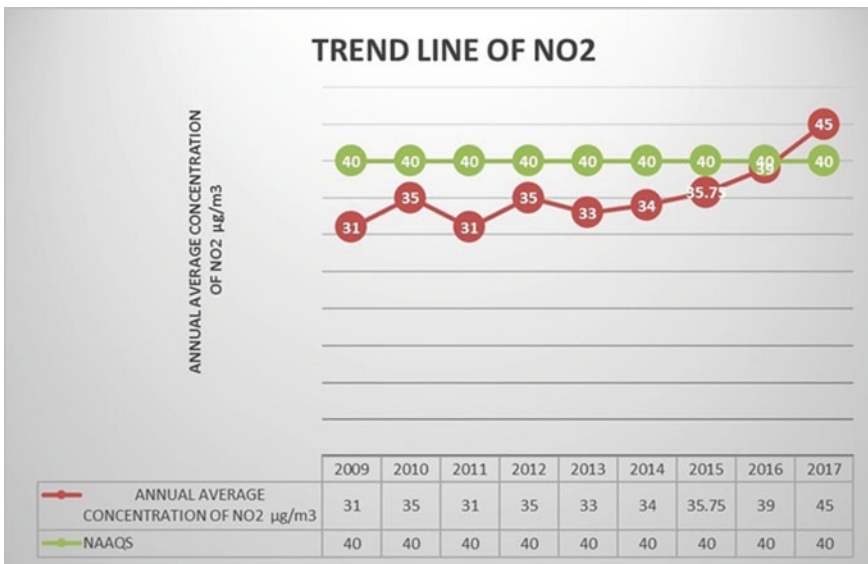


Fig. 4 Annual average concentration of NO₂ for the years 2009–2017. *Source* CPCB-ambient air quality data for the year-wise

5 Impacts of Air Pollution

The impact of air pollution ranges from mild to severe especially from the health perspective. These include breathing problems, asthma, physiological changes in heart and lungs, neurological disturbances, preterm birth, infant mortality, and morbidity. The World Health Organization (WHO) evaluates that annually 800,000 deaths occur due to air pollution [16]. There are effects associated with both short-term and long-term exposure to air pollution. According to medical research, long-term exposure to air pollutants is mainly responsible for increasing the chances of respiratory diseases like allergies, asthma, flu, heart diseases, and lung cancer. The victims include young children, the elderly, persons who are already suffering from other diseases and persons with poor background [17]. WHO recognizes air pollution under non-communicable diseases (NCDs) category, responsible for adult deaths reporting from 24% heart disease, 25% from stroke, 43% from chronic obstructive pulmonary disease and 29% from lung cancer [17]. According to a paper published in the *Lancet*, Uttar Pradesh had the second-highest victims of air pollution among all Indian states as of 2016, predominant cities being Kanpur and Lucknow [18]. According to UPENVIS, 0.4 million disability-adjusted life years are lost every year in Uttar Pradesh due to air pollution. This costs the state about Rs. 2.6 billion. A study by the Usha Gupta Institute of Economic Growth and the Bhimrao Ambedkar College has done the economic study predicting as saving Rs. 213 million if Kanpur meets the air quality standards [18].

Although air pollution had a greater impact on health, other issues due to the increase in pollutant concentration are many. Particulates reduce visibility to a significant level, and it becomes difficult to see beyond 40–60 km (25–35 miles) that is about one-fifth the distance one could normally see without any pollution. NO_x and SO_x are responsible for producing acid rain which is equally harmful to living and material things.

6 Government and Local's Initiatives

Central and state governments, pollution monitoring bodies and other local bodies have undertaken various measures to curb this growing menace of air pollution, but the result is far from achieving the objective either due to lack of proper implementation of plans, poor coordination or target specific strategies. Some of the initiatives taken under the plan are tightening emission standards, strengthening the “pollution under control” system by laying the rules for using new equipment and strictly adhering to the rules for the used vehicles, introduced public vehicles running on CNG and phasing out old vehicles. For combating particulate matter, the concerned authorities have closed down 12 polluting industries and initiated

other advance techniques to clean the air, which includes planting more trees along roadsides, removing construction debris from roads, accelerated construction and demolition work, proper check on the use of adulterated petrol, better power supply to cut off the use of generators, green buffer zones have been created, and garbage heaps have been removed among others [19].

Some of the measures as recommended by the studies discussed in the previous section have been presented here. They have suggested that the city needs at least 27 continuous air monitoring stations to record data from all perspective [2]. The city needs to stimulate public transport, better road structure to curb road dust. An energy-efficient plan to check the emissions from the power plant or shift towards using green technology for electricity production is much needed. Some of the studies have projected vehicular growth based on vehicle category as two-wheelers: 8% three-wheelers: 18% four-wheelers: 9% bus and trucks 16% and LCV: 16%. Considering the above projections, some of the action plans recommended by the studies are implementation of BS-V and BS-VI norms, switch to electric and hybrid vehicle, ethanol mixing, bio-diesel, maintenance of vehicles, banning of 15-year-old private vehicles, increasing use of public transport, particulate control system in industry, changing the location of air polluting industries, use of LPG as domestic fuel, sufficient supply of electricity, better construction practices, constructing paved roads, wetting the road to prevent dust suspension, ban on open burning. To achieve the best possible results, these strategies should be used in combination. The study has also analyzed the reduction in pollutant levels in the quantitative term by implementing the above measures as by banning old private vehicles alone, led to the reduction in PM10 level from 26% in 2012 to 21% in 2017. It may be further noted that reducing vehicular load is directly proportional to road dust reduction. This can be done by preventing the entry of vehicles in critical areas, especially during winter months. Another important measure suggested is to construct a network of mass rapid transit systems, elevated railways, flyovers at all railway intersections leading to a 20% reduction in vehicular emission and considerable improvements in air quality [8].

Recently, IIT-K has sent a proposal to the state government to seek approval from the civil aviation ministry for creating artificial rains using cloud cover, which has been under consideration. IIT Kanpur was given a grant of Rs. 15 lakh from the state government to experiment on the option of artificial rains. The scientists have finished their experiments and are ready to execute [20].

7 China's Air Pollution Scenario and Policy Interventions

In China, the early phase of economic development was powered by the manufacturing sector mainly dependent on coal-burning and industrial processes. The era after 1980 is mainly responsible for emitting CO₂, SO₂, NO_x, and PM at a large

scale. Recently, vehicular emission has also emerged as another source, contributing to the increase in the concentration level of these pollutants, especially in the urban areas. Global Burden of Disease Study (GBD) Report (2010) has estimated that one year of exposure to pollutants leads to 1.2 million premature deaths in China [21]. On the economic front, as shown by multiple studies, the increasing pollution level is responsible for the losses in the form of gross domestic product (GDP) between 1 and 7% [22]. The current scenario comprises SO₂, PM_{2.5}, all particulate matters (PMs) and ground-level ozone (O₃) as major pollutants [23]. The worsening condition is due to the rising level of PM_{2.5} and O₃. The scientist has explained this rising as the “air pollution complex”, a concept formally proposed and defined by Tang in 1997 [24]. SO₂, NO₂ and VOCs get converted to PM_{2.5} where O₃ concentration is higher due to the increased rate of oxidation [23]. China's air pollution scenario has been studied in three phases. Phase 1 includes the 1970–1990 time period where dominating sources were coal-burning power plants and households and industries contributing to SO₂, TSP, NO_x, and CO emission [24]. Phase 2 was the transition period from 1990 to 2000, in addition to phase 1 pollutant, increasing vehicular emission has contributed to raising the level of NO_x, and releasing of VOCs [25]. Phase 3 was from 2000 till present where all the factors previously responsible get enhanced spreading to the regional level and worsening the quality of megacities.

China's environmental protection system is based on 5 pillars—(1) environmental protection laws and emission standards; (2) time-specific planning; (3) specific regulatory measures; (4) other specific actions and (5) collaboration with state authorities [23]. China's Environmental Protection plans were developed in the early 1980s and become more stringent after the PM_{2.5} crises happened in 2012–2013. Pollution control planning in China has been divided into three stages.

Stage I—Until 2005

The measures adopted by China during this stage were (1) local governments control the air pollution within their area; (2) focus on coal utilization sources; (3) emission targets for stack concentration; (4) polluter pay principle had been applied. Special measures were adopted in Beijing due to its worst air quality such as substituting coal, desulphurizing, dust collection and combustion techniques emitting lower NO_x in power plants. Some other measures taken were, Increasing vegetation coverage and minimizing road dust and dust from construction sites, and a set of actions on vehicular pollution including setting a limit on emission for new vehicles, the use of quality rich fuel, phasing out of old vehicles [23, 26]. However, due to the growth in the number of vehicles and contributions from nearby industrial centres [23, 27], these efforts become insignificant in improving air quality. These strategies were adopted to target specific pollutants like NO_x and VOCs.

Stage II—2006–2012

The focus of policies during this phase was getting rid of SO₂ completely and the alternatives for saving energy. For both the key factors, specific targets were set, 10% reduction from the 2005 level for SO₂ and reduction in energy consumption to

20% per unit of GDP from the 2005 level [23]. This has been reported by several studies that although the targets were achieved, there was a trivial improvement in air quality. This was due to the lack of diligence on the part of local government. In the 12th FYP, the focus shifted to SO₂ and NO_x [23]. The failure of policies was due to the focus on two parameters, while the transformation process from primary to secondary pollutants involving nonlinear complexity had been neglected.

During this phase, special action was taken by Beijing and surrounding territories as a part of their preparations for the 2008 Olympics. The measures adopted were very rigorous and were implemented in few identified key areas, which were complete shutdown of powerplants, limiting vehicle usage, stringent regulation of dust from construction activities and the prohibition on stubble burning [23, 26]. These measures resulted in substantial improvements in air quality during and after the Olympics, but the effects were temporary and washed out by the end of October 2009. Some of the measures like plant closure and traffic control were adopted during other events also like World Exposition in Shanghai (2010) and the Asian Games (2010) [23].

Stage III—2012–Till Present

To tackle the PM_{2.5} crises in 2013, the state council and Ministry of Environment Protection have issued a specific action plan featuring ten points agenda. During this phase, both qualitative and quantitative aspects of air quality were taken into consideration by setting proper time-bound targets [23]. The trend line for PM_{2.5} from the year 2008 to 2015 shows that the policy actions have yielded results [28].

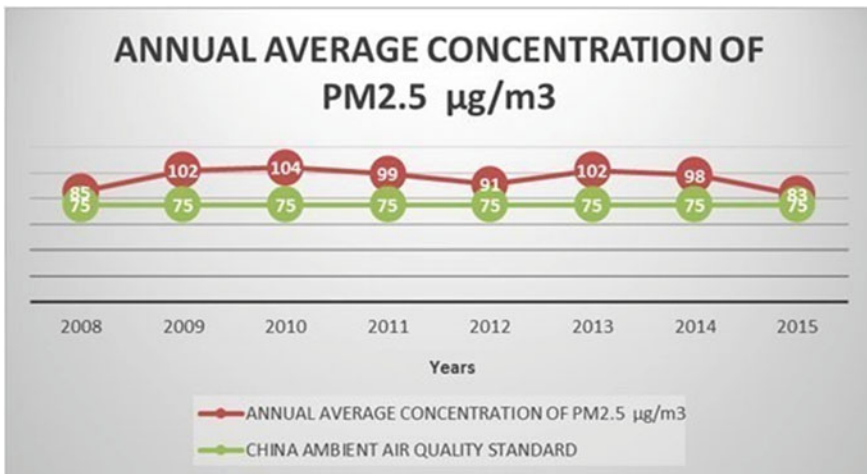


Fig. 5 PM_{2.5} trend line in Beijing

7.1 *China's Handling of Air Pollution Crises*

India and China both face the same situation in terms of air quality as both are emerging economies facing similar cost-benefit tradeoffs. But China follows a strict stringent system of environmental protection which works at a regional level, while policy implementation in India has a loose end. Comparing the results of quantitative analysis of pollutants based on reports published in 2015, it has been found that the level of overall particulate matter in India is greater than that in China. The data shows that PM_{2.5} level was falling in china recording 17% decrement between 2010 and 2015, while in India, it has been increased to 13% during the same period [29]. Before 2008, the pollution level in China was rampant recoding a loss of about 133 million workdays resulted in a loss of 1.34% of GDP. According to a 2015 report by RAND Environment, Energy and Economic Development Program, between 2000 and 2010, air pollution-related health problems in china and lost labour productivity have reached 6.5% per year of China's GDP [30].

Both the countries have geared up to tackle this menace in full-fledged form. According to the World Bank report, 2016, air pollution-related welfare activities account for 8.5% of India's GDP. These activities include measures ranging from a graded response action plan (GRAP) to fixing catalytic converters in vehicles for emission reduction. In comparison with this, China has introduced the "airborne prevention and control action plan" in 2013 and recognized coal as the major force of air pollution and started putting a cap on its use. China has also pursued some innovative solutions like building a 7-m tall smog-free tower in Beijing in 2016, a 328 feet tall air purifier was constructed in Xian in 2017 decreasing the level of PM_{2.5} by 15% [29]. Apart from this, China has also been investing in clean coal technologies along with the USA, which covers the use of carbon capture and storage technology and improvements in the efficiency of power plants [29]. China is also increasing the efficiency of power generation by using "ultra-supercritical" facilities which decrease coal dependency for energy production. This results in the generation of 286 g of coal equivalent (gce) per kilowatt of power produced, which is less as compared to the USA (375 gce). In its Thirteenth Five-Year Plan released in 2016, the target of China is an 18% reduction in PM_{2.5} level and 140 million tonnes reduction in coal production by 2020. To achieve the target, 40% of factories in China have been shut down in 2017, resulting in a 50% reduction in PM_{2.5} levels in the city of Linfen which was designated as the heavily polluted city until then [29].

8 Conclusion

The conclusion of the study presented here identifies particulate matter as the main driver of pollution level in the city has been discussed in various studies previously, contributing nearly 76% to the pollution level. Most of the time particulate fractions

(PM_{2.5}, PM₁₀, SPM) exceeded the standards set by NAMP. Gaseous pollutants like sulfur dioxide concentration have mounted after 2010 and it's still in the rising phase according to the recent studies [2], and nitrogen dioxide level remains at par with PM₁₀, sufficient in causing potential harm to health. The main reason for the increasing pollution level is the heavy traffic density and unfavorable climatic conditions adversely affecting the surrounding air. The review study suggested that the inhalation of polluted air is responsible for major health problems such as breathing problems, bronchitis, asthma, heart diseases, pneumonia, and lung cancer. Vehicular pollution also affects the vegetation, the roadside plant faces heavy stress due to an increased level of gaseous pollutants, and their biogeochemical cycle is getting disturbed impacting the ecological cycle more broadly.

The paper also presented the air pollution scenario of our neighboring country China as most of the cities in China are also facing the worst air quality situation in the same way as India. Although China has tightened the rope in tackling the situation after 2010 only, their efforts have resulted in refining the air quality in a significant way, while India is still dangling in the middle of the crises with 14 of its cities has been featured in the WHO worst cities list in terms of air quality.

Air pollution is a global phenomenon. Every country is facing the burden of rising pollution levels and is under serious threat. At international forums, talks have been going on among the countries to fight against air pollution on the common ground. Every country has taken responsibility on its part to reduce its emission and set targets according to one's capability. A report published by WHO stated that countries are working deliberately in curbing the pollution menace and appreciated India's efforts in switching to clean household energy use through Pradhan Mantri Ujjwala Yojana.

There is an urgent need to undertake specialized studies targeting specific sources. The heavily polluted area should be marked, and actions pertaining to a particular scenario taking into account climatic and geographical factors should be taken. While initiatives such as closing down coal-fired plants, shifting the location of industries, the odd-even scheme of Delhi government to control traffic movement and vehicular emission, ban on crackers during Diwali, ban on stubble burning are welcoming steps, but still, much needs to be done to come down pollution within the standard limits. India needs to streamline its administrative structure in Environment Protection Agencies and follow the example of China where regional administration plays a greater role in handling the issue within its jurisdiction. Decentralizing the efforts by empowering local authorities to take responsibility for the pollution scenarios in their area should help in the long run. Along with the local, state and central government should work towards a common cause with area-specific approaches as air pollution is a complex problem and pollutants just not remain concentrated at a particular place but travel long distances, beyond governmental control.

References

1. WHO Global Urban Ambient Air Pollution Database (2016) <https://www.who.int/airpollution/data/cities/en/>
2. Times of India, 14 of world's 15 most polluted cities in India, May 2, (2018), http://timesofindia.indiatimes.com/articleshow/63993356.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
3. Wu Y (2010) Understanding economic growth in China and India: a comparative study of the selected issue. World Scientific Publishing Co. Ltd. ISBN 9814287784/981-4287- 78-4/9789814287784
4. Central pollution Control Board (CPCB). National Ambient Air Quality Standards (2009). <http://www.cpcb.nic.in/NationalAmbientAirQualityStandards.php>, 22-5-14
5. Anusha: Importance of national ambient air quality standards (2016) <http://greencleanguide.com/importance-of-national-ambient-air-quality-standards/>
6. Census 2011-Census of India. www.censusindia.gov.in/2011census/PCA/PCA_Highlights/.../India/Chapter-1.pdf
7. Meteoblue. <https://content.meteoblue.com/en/content/view/full/2879>
8. Energy Economic times (2018) <https://energy.economictimes.indiatimes.com/news/coal/worlds-worst-air-kanpurstruggles-to-track-pollution/64183796>
9. The Air Pollution Knowledge Assessment (APnA) City Program report (2015) www.urbanemissions.info/india-apna/
10. Sharma M (2010) Air quality assessment, emissions inventory and source apportionment studies for Kanpur City. Indian Institute of Technology, Kanpur
11. Sharma M, Maloo S (2005) Assessment and characterization of ambient air PM10 and PM2.5 in the City of Kanpur, India. *Atmos Environ* 39:6015–6026
12. Gaur A, Tripathi SN, Kanawade P, Tare V, Shukla SP (2014) Four-year measurements of trace gases (SO₂, NO_x, CO, and O₃) at an urban location, Kanpur, Northern India. *J Atmos Chem* 71(4):283–301
13. CPCB-National Air quality monitoring programme. www.cpcb.nic.in/monitoring-network-3/
14. ENVIS Centre on control of pollution water, air, and noise, central pollution control board sponsored by Ministry of Environment and Forests, Govt of India. www.cpcbenvis.nic.in/air_quality_data.html
15. Shukla P (2013) Air pollution in select Indian Cities, TERI
16. Arbex MA, de Souza Conceic GM, Cendon SP (2009) Urban air pollution and chronic obstructive pulmonary disease-related emergency department visits. *J Epidemiol Community Health* 63:777–783
17. World Health Organization (2002) World health report, reducing risk, promoting healthy life, WHO, Geneva, Switzerland, <http://www.who.int/whr/2002/en/>, 20-03-14
18. Centre for Science and Environment study on Air Pollution on the rise in Kanpur <https://www.cseindia.org/air-pollution-on-the-rise-in-kanpur-says-latest-cse-study> 558
19. Business Standard, India-Air Pollution (2018) <https://www.business-standard.com/article/current-affairs/india-air-pollution-kanpur-delhi-among-14-of-15-most-polluted-cities-in-the-world-shows-who-pollution-index-top-10-highlights>
20. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, AlMazroa MA, Amann M, Anderson HR, Andrews KG (2013) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions 1990–2010: a systematic analysis for the global burden of disease study 2010. *Lancet* 380:2224–2260
21. Zhang SQ, Huang D (2011) Controlling fine particulate pollution and mitigating environmental health damage. *Environ Prot* 16:25–26
22. Jin Y, Andersson H, Zhang S (2016) Air pollution control policies in China: a retrospective and prospects. *Int J Environ Res Public Health* 13(12):1219. Published 2016 Dec 9. <https://doi.org/10.3390/ijerph13121219>

23. Shao M, Tang X, Zhang Y, Li W (2006) City clusters in China: air and surface water pollution. *Front Ecol Environ* 4:353–361
24. Chan LY, Chu KW, Zou SC, Chan CY, Wang XM, Barbara B, Blake DR, Guo H, Wai Yan T (2006) Characteristics of nonmethane hydrocarbons (NMHCs) in industrial, industrial-urban, and industrial-suburban atmospheres of the Pearl River Delta (PRD) region of south China. *J Geophys Res Atmos* 111:1937–1952
25. Zhang S, Wu D, Xie X, Hu Q, Zou W, Yi R, An S, Zheng Y, Yue P, Wan W (2008) Research on achieving Beijing's air quality goal: strategies and measures. Peking University, Beijing
26. Wu D, Xu Y, Leung Y, Yung CW (2015) The behavioral impacts of firm-level energy-conservation goals in China's 11th Five-Year Plan. *Environ Sci Technol* 49:85–92
27. China Power: Is air quality in China a Social Problem (2018)? <https://chinapower.csis.org/air-quality/>
28. <http://www.stateair.net/web/historical/1/1.html>
29. Chen S-M, He L-Y (2014) Welfare loss of China's air pollution: how to make personal vehicle transportation policy. *China Econ Rev* 31 (Beijing: Chinese Economists Society) 106
30. Hindustan Times (2018) <https://www.hindustantimes.com/lucknow/kanpur-notice-to-7-government-departments-for-failing-to-check-air-pollution/story>