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Original Article

Degradation of Air Quality (PM_{10}) with Seasonal Change and Health Risk Assessment in Metro City Kolkata

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Abstract

Over the last few years, the whole nation is consistently facing a severe level of air pollution during the winter season. Air pollution level in all over India has started to get aggravated during the post-monsoon season due to an association of both atmospheric and anthropogenic factors. PM_{10}. i.e. inhalable particles with a diameter less than or equal 10 micrometres, is a criteria air pollutant out of total twelve in India having great importance. In this study, seasonal variation of PM_{10} concentration was measured near Jadavpur, Kolkata from December 2017 to March 2018. During the study period results of ambient air quality monitoring data for the average concentration of PM_{10} ranged between 103.67 – 323.70 µg/m^3. It is observed that in 100% of the cases, the 24hr average concentration of PM_{10} contravened the NAAQS (100 µg/m^3) limit. The maximum concentration of PM_{10} was observed during the winter season (238.81±63.12 µg/m^3) from January to February. To understand the existing air quality scenario, the Air quality index (AQI) value is computed based on PM_{10} concentration which is belonged to 'Moderate' to 'Poor' categories. It is observed that in December about 43% of days belong to the 'poor' category and 57% is of 'moderate', wherein the month of January only 25% days are a part of the moderate category, and the rest are of poor category. In the case of February month, only 17% of poor days are observed, and the air quality scenario gets improved with approaching summer season as in March air quality became moderate. Thus it is noticed that PM_{10} is a critical pollutant at this site in Kolkata. In this study, the number of higher rates of mortality and morbidity risk, respiratory diseases, cardiovascular diseases and chronic obstructive pulmonary disease risk for an exposed population is also estimated due to exposure to $PM_{10.}$

Keywords: *Air Pollution, PM_{10}, AQI, Health effects*

Introduction

Air quality is a rising concern for people living in India as well as in the world. As per the World Health Organization, 91% of the global population lives in unsafe breathing place where the air quality exceeds the WHO standard. According to WHO 2018 database (WHO, 2019a), out of the world's 20 most polluted cities, 15 cities have belonged to India (AirVisual, 2018). Urban air pollution in India has rapidly increased due to the lack of proper steps taken by the government towards growing population, increasing motor vehicle numbers, the use of fossil fuels, open biomass burning and lack of maintenance of transportation systems, which indicates ineffective implementations of environmental regulations. Besides those all factors, another important factor is a meteorological condition which acts as the catalyst to regulate air pollution.

Outdoor air pollution is a significant cause of disease and death globally, with the effects ranging from the hospital emergency room visits and admission to the risk of premature death. As per the WHO 2018 database, ambient air pollution is linked with about 4.2 million premature deaths globally were 25% of ischaemic heart disease, 24% of stroke, 43% of chronic obstructive pulmonary disease, 29% of lung cancer and 17% of acute respiratory infections. There is much strong evidence which showed that the Particulate Matter has a public health concern (Dockery & Pope III, 1994; Feng et al., 2019; Haque & Singh, 2017; Kampa & Castanas, 2008) as it is capable of penetrating deep into lung passageways and after entering into the bloodstream cause cerebrovascular, cardiovascular and respiratory diseases(WHO, 2019b).

In this study, outdoor PM_{10} pollutant concentrations are measured to give special emphasis on the seasonal effects on the air quality and in the meantime, AQI is also calculated. On the other hand, the rate of mortality and morbidity risk due to PM_{10} exposure is accessed from several case studies.

Materials and Methods

2.1. Monitoring Site

In the eastern part of India, the City of joy Kolkata is located in the east bank of the Hooghly river. This subtropical metropolitan city covered an area boundary of 185 square kilometres, and it is the third-largest city in India, with almost its 4.497 million population (DCOWB, 2011). The monitoring site located at Jadavpur, Kolkata near Jadavpur University at Gate No. 3 (22°29'53.15" North, 88°22'12.82" East). This selected location is one of the busiest areas with the significant roadway named Raja Subodh Chandra Mallick Road, many renowned research and academic institutions, school and Medical College and Hospital spanning through both sides of this road. Here the gathering of school college students, passengers, roadside vendors, etc. together at a high number takes place in rush hour mainly, so the pollution level of this area is of great importance in an aspect of their health. Being busiest the speed of the car is low, and traffic density is high which also helps the cars to emit more pollutants.

2.2. PM_{10} Concentration

To understand the seasonal variation and episodic rise of the air pollution in the study region, the air quality monitoring spanned over four months from December 2017 to March 2018 at Jadavpur, Kolkata (Fig. 1). The air pollutant PM_{10} mass concentrations at the study site were measured in three distinct seasons viz., post-monsoon (December 2017), winter (January to February 2008) and summer (during March 2018). The PM10 mass concentrations were being monitored by the standard gravimetric method (CPCB, 2013) using Respirable Dust Samplers (Envirotech APM 460 BL). The sampling was carried out for 8 hours, and the receptor height was 1.46 m above the ground level, which is at the human breathing zone.

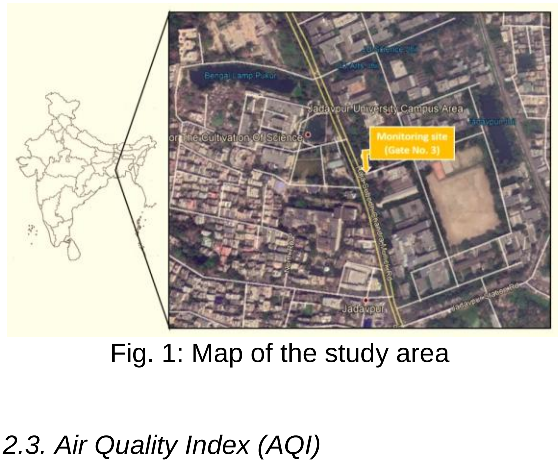

Fig. 1: Map of the study area

2.3. Air Quality Index (AQI)

The Air quality index (AQI) is a technique to recognise the existing air quality scenario that was calculated using the standard Indian AQI procedure (CPCB, 2014). This method has been developed based on the dose-response relationship of various criteria air pollutants. The AQI method involves the formation of sub-index (I_p) for each pollutant concentration (C_p) based on the 'linear segmented principle'. The mathematical equation for calculating sub-index is as follows

$$\mathbf{I_P} = [\{(\mathbf{I_{HI}} - \mathbf{I_{LO}})/(\mathbf{B_{HI}} - \mathbf{B_{LO}})\} \times (\mathbf{C_P} - \mathbf{B_{LO}})] + \mathbf{I_{LO}}$$

B_{HI}= Breakpoint concentration greater or equal to C_P.

B_{LO}= Breakpoint concentration smaller or equal to C_P.
I_{HI} = AQI value corresponding to B_{HI}
I_{LO} = AQI value corresponding to B_{LO}
Finally; AQI = Max (Ip) (where; p= 1, 2... n; denotes n pollutants)

Table 1 represents the breakpoints for PM_{10} with a colour scheme to represent the AQI bands and shows health statements for every AQI category.

Table 1: Air quality index (AQI) category with Health statements

AQI Category (Range)	PM_{10} – 24hr (μg/m³)	Associated Health Impacts
Good (0 – 50)	0 - 50	Minimal Impact
Satisfactory (51 – 100)	51 - 100	May cause minor breathing discomfort to sensitive people
Moderately Pollutant (101 – 200)	101 - 250	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201 – 300)	251 - 350	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease
Very Poor (301 – 400)	351 - 430	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401 – 500)	430 +	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Results

3.1. Descriptive analysis of pollutant concentration

The PM_{10} concentration was measured from December 2017 to March 2018, and a total of twenty-six observations took place. The PM_{10} mass concentration ranged between 103.67–323.70 μg/m³. 100% of the observed daily average PM_{10} mass concentration exceeded the National Ambient Air Quality Standard (NAAQS) as specified by the Central Pollution Control Board (CPCB, 2009). From Fig. 2 it is observed that the concentration of PM_{10} started to show an increasing trend in December (222.38 ± 52.97 μg/m³) which attained its maximum value in the month of January (284.55 ± 38.19 μg/m³), further it started to show a decreasing trend from the end of February (177.84 ± 51.33 μg/m³) to March (159.74 ± 34.28 μg/m³). This was because of the seasonal variation, in case of December it's a month of winter approach and in winter season, i.e. the month January and February due to low temperature, low wind speed leads to stable atmospheric conditions for which particulate matter gets trapped near ground level (Bathmanabhan & Saragur Madanayak, 2010; Ganguly, Sharma, & Kumar, 2019) so the particulate matter concentrations showed the increasing trend (Ali et al., 2015)**.** On the other hand at the end of February, the atmospheric temperature, as well as wind speed, started to increase and those factors lead to the unstable lower atmosphere (Li, Guo, Han, Tian, & Zhang, 2015) which help out the pollutants to be dispersed during the approaching summertime (Ali *et al.*, 2015)**,** i.e. the month of March, and for these probable reasons the PM_{10} concentration get lowered.

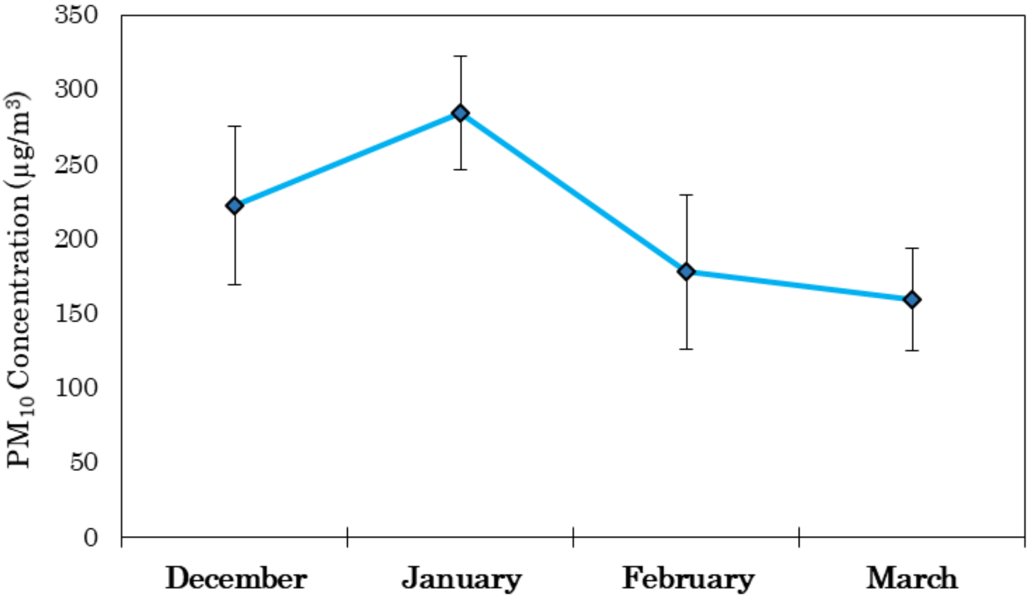

Fig. 2: Monthly variation of PM_{10} mass concentration

3.2. Descriptive analysis of AQI variation

In Fig.3 it is seen that in December, 57% of the monitoring days the air quality falls under the moderately polluted category, where rest 43% days comes under the poor category, which may have cause breathing discomfort and heart disease to people on prolonged exposure. It is also clearly observed that the few days at the end of December only fall under the poor category as at this time the winter season started to approach in the Indian subcontinent.

In January this scenario became deteriorated as 75% of the monitoring days came with Poor category and at the end of February, the air quality became improved, about 83% of days comes under the moderately polluted category as the summer season came. In March, 100% monitoring days came under the moderately polluted category, and the air quality started to improve with the summer season.

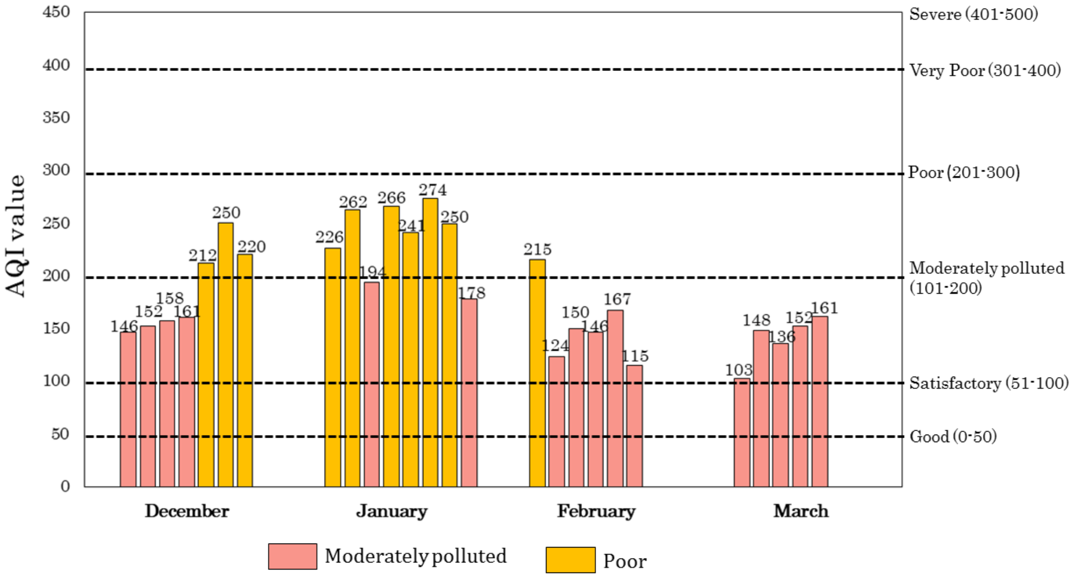

Fig. 3: Daily AQI variation

3.3. Health risk associated with PM_{10} concentration

It is reported from various epidemiological studies that the exposure to particulate matter causes respiratory diseases like asthma, chronic obstructive pulmonary disease (COPD), cardiovascular diseases, Ischaemic heart disease, oxidative stress, Neurobehavioral deficit, alter host defence, lung tissue damage and so on and ultimately lead to premature death and contribute to cancer (CPCB, 2012; Manojkumar & Srimuruganandam, 2019). In the present study, it was observed that the daily 24 hr. Mean PM_{10} concentration was ranged between 103.67 – 323.70 µg/m^3 which is about 2 to 6 times higher than the WHO standard (50 µg/m^3, 24-hour) and also exceeds the NAAQS limit (100 µg/m^3, 24-hour). The percentage increase in relative risk (RR) of mortality, respiratory disease, cardiovascular disease and lung cancer due to exposure to increased PM_{10} concentration is studied by many researchers, and the values are well documented (Table 2).

Table 2: Increasing disease-specific Relative Risk (RR) with Increment in PM_{10} exposure

SL. No.	Type of health impact	Increment in exposure (µg/m^3)	Percentage increase in RR (95% CI)	Reference
1	Daily mortality	10	0.7 to 1.6	Dockery & Pope III, 1994
		10	1.1	Forastiere *et al.*, 2007
		14.4	0.74	Alessandrini *et al.*, 2016
		10	3.9	Khaniabadi *et al*., 2017
2	Cardiovascular mortality	10	0.8 to 1.8	Dockery & Pope III, 1994
		10	4.2	Khaniabadi *et al.*, 2017
		10	0.8	Khaniabadi *et al.*, 2019
3	Respiratory mortality	10	1.5 to 3.7	Dockery & Pope III, 1994
		10	6.2	Khaniabadi *et al.*, 2017
4	Cardiovascular disease	10	0.9	Khaniabadi *et al*., 2019
		1	1.003	Vaduganathan *et al*., 2016
5	Asthma disease	10	0.8 to 3.4	Dockery & Pope III, 1994
		10	0.8	Khaniabadi *et al*., 2017
6	Chronic obstructive pulmonary disease (COPD)	10	5.9 and 6.6	Khaniabadi *et al*., 2018
		10	1.7	Dockery & Pope III, 1994
7	Lung Cancer	10	22	Vaduganathan *et al.*, 2016
		10	0.91	Gallus *et al.*, 2008

In the case of daily mortality, it was observed from various epidemiological case studies that both short term and long term exposure in PM_{10} concentration is linked with increased daily mortality. In Rome, Italy, a total of 83,253 people aged above 35 years died, between 1998 and 2001 (Forastiere *et al.*, 2007) and the lower social class of people had suffered from choric diseases especially heart failure, diabetes mellitus, chronic obstructive pulmonary diseases and hypertension before their death and it was observed that short-term increases in PM_{10} concentration were strongly associated with mortality (1.1% increase, 95% confidence limit (CL) = 0.7–1.6%, per 10 µg/m^3). In this study, it was also clearly observed that this PM_{10} concentration effect was more pronounced among the lower-income class and Socioeconomic status (SES) (1.9% and 1.4% per 10 µg/m^3, respectively) rather than the upper-income class and SES (.0.0% and 0.1%, respectively). Another crossover- case study on short-term exposure of PM_{10} associated mortality in susceptible age groups based on the 228,619 elderly (ages ≥65 years) residents of 12 Italian cities were recorded between 2006 and 2010 (Alessandrini *et al.*, 2016). The PM_{10} concentrations with mean values ranging from 49.7 µg/m^3 in Turin to 32.4 µg/m^3 in Ancona. The percentage of changes in natural mortality was associated with a 14.4-µg/m^3 increase in PM_{10} were 0.74% (95% CL: 0 - 1.49%). In the case of long term exposure in PM_{10}, it was also noted from an epidemiological review case study in 1994 (Dockery & Pope III, 1994)**)** that with an increase of PM_{10} with 10 µg/m^3 concentration the daily mortality was increased in the range between 0.7% - 1.6%. In Khorramabad, Iran a study was taken place between 2015 to 2016 where it is noticed that the total mortality associated was 3.9% (95% CI: 3.3-4.5%) for an increase of 10 µg/m^3 PM_{10} concentrations from the baseline concentration of 24 hr WHO annual standard limit (Khaniabadi *et al.*, 2017).

Cardiovascular mortality and respiratory mortality was also associated with PM_{10} and mentioned in several case studies. In Iran, where the annual PM_{10} average concentrations in Khorramabad area was 67.30 µg/m^3 and reached the maximum concentration of 621 µg/m^3 , the relative risk of cardiovascular mortality and respiratory mortality were increased by 4.2% (95% CL: 2.7 – 9.05%) and 6.2% (95% CL: 4.2 – 16.9%) respectively (Khaniabadi *et al.*, 2017), Khaniabadi *et al.*, 2019 also reported that increase in respiratory mortality risk was 0.8% for each 10 µg/m^3 increase in PM_{10} concentration. In another case study (Dockery & Pope III, 1994) it was reported that the increase in the cardiovascular mortality and respiratory mortality was increased in the range between 0.8% -1.8% and 1.5% - 3.7% respectively for an increase of 10 µg/m^3 PM_{10} concentration.

PM_{10} associated with both acute and chronic respiratory diseases are recorded from several case studies. In case of acute effects of PM_{10} on the respiratory system, it was reported that the effects of upper respiratory symptoms, including, runny or stuffy nose, sore throat, wet cough, head cold, etc. were increased by 0.7% with each increment of 10 µg/m^3 daily mean of PM_{10}. In case of lower respiratory symptoms, the effects including wheezing, dry cough, shortness of breath, and chest discomfort or pain were increased by 3% with each Increment of 10 µg/m^3 of PM_{10} by daily mean (Dockery & Pope III, 1994)**.** For chronic exposure in PM_{10} associated hospital admission for respiratory diseases (HA-RD) increased by 0.8% (Khaniabadi et al., 2019) and the risk of asthmatic attacks about 3%, with an increase of 10 µg/m^3 PM_{10} concentration (Dockery & Pope III, 1994). In an Iranian city, Kermanshah daily hospitalisation for chronic obstructive pulmonary disease (COPD) due to exposure to PM_{10}, O_3, SO_2 and NO_2. From the result, it was observed that in the year 2012 COPD morbidity has increased with respect to 2011, for PM_{10} exposure up to 108 persons with an increase of the annual mean of PM_{10} concentration from 85.8 to 133.9 µg/m^3. In 2011 5.9% (95% CI 3.6–8.5%) and 2012 in 6.6% (95% CI 4.7– 9.3%) of daily hospitalization were attributed by PM_{10} (Khaniabadi *et al.*, 2018).

A cross-sectional study in the Lombardy region of northern Italy association between PM_{10} concentration levels and 6000 patient hospital admission due to acute CV events was studied from 1st September 2004 to 30th September 2007. Daily 24 hr. PM_{10} concentration was observed during the study period that was 40.2 ± 1.8µg/m^3 and acute heart failure (RR 1.004, 95% CI 1.001- 1.008), acute hospitalizations for composite CV-related events (RR 1.003, 95% CI 1.002-1.005) and atrial fibrillation (RR 1.008, 95% CI 1.003- 1.012) was associated with 1 µg/m^3 increase of PM_{10} concentration. It was also noted that rates of lung cancer 22% increase with every 10 µg/m^3 increase (Vaduganathan et al., 2016). With short-term exposure at PM_{10} concentration for each 10 mg/m^3 increase, the risk of cardiovascular diseases (HA-CVD) increased by 0.9% (Khaniabadi *et al*., 2019).

Discussion

In this study, PM_{10} concentration was measured near Jadavpur University, Kolkata from December 2017 to March 2018. The analysis of particulate mass concentration showed that in 100% of the observed day denied the 24 hr. average concentration standard limit prescribed by the Central Pollution Control Board that is 100 μg/m^3. After calculating the AQI it was noticed that maximum poor days came under the month of January which is belonged to the winter season and the rest days came under the moderate category which was an indication of bad existing air quality of this monitoring area. Also after reviewing various epidemiological case studies, health effects associated with the severity of PM_{10} exposure was clearly understood.

Conclusion

Further studies are needed to quantify the health effects due to exposure to air pollutants in urban atmospheres and also proper regional policy has to be implemented to decrease the air pollution level. Also, public awareness, use of advanced technologies, reduction of fossil fuel consumption, biomass burning, the proper implication of existing rules and regulations and careful monitoring of criteria air pollutants will play an important role as control strategies.

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