Air Pollution in Kolkata: An Analysis of Current Status and Interrelation between Different Factors

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DOI: 10.2478/v10306-012-0012-7

Abstract

Kolkata, one of the fastest growing metropolises in India has been suffering from air pollution for many decades. The rapid urbanization coupled with ineffective government control has been fuelling this problem. The study aims to portray the current air pollution situation in this megacity as it analyses the present level of different air pollutants like Suspended Particulate Matter (SPM), NO2 and SO2. The result of the analysis shows the critical level of air pollutants specially the SPM and NO2 in different parts of city. By zoning the city into residential, commercial and industrial areas, the result shows the difference between the levels of pollution in each area. The second part of the study explored the seasonal variation of air pollution and it has been found all of the pollutants reach its highest concentration during winter. Extending the study, the paper also tries to establish the relationship between the air pollutants and metrological factors by using the

Spearman's Rank Correlation. The results show an inverse relation between the concentration of pollutants and the metrological factors such as precipitation, wind, temperature and relative humidity. Finally, a calculation of the change in pollution level during the two festive seasons is carried out and an increase in SPM concentration has been found during the celebrations of Kali Puja and Diwali.

Key Words: Air Pollution, Seasonal variation, Metrological factors, megacity

Abstrakt

Kalkuta, një nga metropolet me rritje më të shpejtë në Indi, vuan nga ndotja e ajrit për shumë dekada. Urbanizimi i shpejtë, bashkë me kontrollin joefektiv të qeverisë, ka nxitur këtë problem. Studimi ka për qëllim të paraqesë situatën aktuale të ndotjes së ajrit në këtë megaqytet duke analizuar nivelin e tanishëm të ndotësve të ndryshëm të ajrit, si: grimcat (Suspended Particulate Matter-SPM), NO2 dhe SO2. Rezultatet e analizës tregojnë nivelin kritik të ndotësve të ajrit, posaçërisht SPM dhe NO2 në pjesë të ndryshme të qytetit. Me ndarjen e qytetit në zona: të banimit, ato komerciale dhe industriale, rezultatet tregojnë dallimin në mes të niveleve të ndotjes në çdo zonë. Pjesa e dytë e studimit, hulumton variacionin sezonal të ndotjes së ajrit. Këtu është konstatuar se përqendrimi i të gjithë ndotësve është gjatë dimrit, kur, si rrjedhojë, është më i lartë. Me shtrirjen e studimit, ky punim, gjithashtu, përpiqet të krijojë marrëdhënie ndërmjet ndotësve të ajrit dhe faktorëve meteorologjikë duke përdorur Korrelacionin e ranguar të Spearman-it. Në bazë të rezultateve del se ka një lidhje të anasjelltë midis përqendrimit të ndotësve dhe faktorëve meteorologjikë siç janë: era, reshjet, temperatura dhe lagështia relative. Së fundi, është kryer një llogaritje e ndryshimit të nivelit të ndotjes në dy sezonet festive dhe një rritje e përqendrimin të SPM. Me këtë rast është konstatuar se gjatë festimeve të Kali Puja dhe Diwali përqendrimi është më i madh.

Апстракт

Калкута, една од најбрзо растечките метрополи во Индија веќе неколку децении има проблеми со загадувањето на воздухот. Брзата урбанизација заедно со неефикасната контрола на владата дополнително го разгорува овој

проблем. Студијата има за цел да го прикаже на тековната ситуација со загадувањето на воздухот во овој мега град преку анализирање на сегашното ниво на различни загадувачки материи во воздухот како суспендирани честички, NO2 и SO2. Резултатот на анализата покажува критично ниво на загадувачите на воздухот посебно за суспендираните честички и NO2 во различни делови на градот. Преку одредување зони на градот во станбени, комерцијални и индустриски области, резултатот ја покажува разликата помеѓу нивоата на загадување во секоја област. Во вториот дел од студијата се истражува сезонска варијација на загадувањето на воздухот која доведе до резултат кој укажува дека сите загадувачи ја достигнуваат својата најголема концентрација во текот на зимата. Понатаму преку студијата, исто така, се воспоставува врска помеѓу загадувачите на воздухот и метеоролошките фактори со користење на Спирмановиот коефициент на ранг корелација. Резултатите покажуваат инверзен однос помеѓу концентрацијата на загадувачите и метеоролошките фактори како што се врнежи, ветер, температура и релативна влажност. На крајот се пресметува промената на нивото на загаденост на текот на двата празника при што се воочува зголемување на концентрацијата на суспендирани честички за време на прославата на Кали пуја и Дивали.

1. Introduction:

In general, cities in developing countries can well be compared to islands in a sea of deprivation and poverty. Kolkata is not an exception! The former capital of the British India is experiencing "growing up" pains as it endeavours to reclaim its lost glory. As the city grows physically to keep up with its economic growth, it counters several environmental degradations. Air pollution is one of them. A report published by world health organization in 2002 shows around 4.6 million people die each year because of direct impact of air pollution (WHO 2002). Rapid and unplanned urbanization making this problem more acute in many megacities in developing countries (UNEP 1999). Kolkata being one of the fastest growing metropolis in India, is experiencing this problem lately. The influx of large population from the rural areas putting immense pressure in the city's infrastructure and it is getting difficult to manage it properly (Ghose *et al* 2004; Agrawal *et al* 2003). As a result, the level of pollution in the city is growing at an alarming rate over the past several years.

Several factors results the air pollution level in Kolkata. One of the main factor is transportation (Mondal *et al* 2000). Abundance of poorly maintained vehicles, use of petrol fuel (although government is in a process to phase out these vehicles) and poor controlling is making transportation the major air-polluting sector (Mukherjee and Mukherjee 1998; Kazimuddin and Banerjee 2000). Besides, there are three thermal power plants in and around Kolkata, which also affects the air quality (Ghose 2009). Along with these two major factors, some small industries operating in the city contribute to the air pollution. The study also identifies the contribution of generators used during power cuts to pollute the air of the city to some extent.

In this study, we tried to analyze the air pollution level of Kolkata from different viewpoints. The study starts with some general aspects about the geography and climate of Kolkata, which influences the pollution levels immensely as discussed later in the study, followed by some startling reports about the effects of air pollution in Kolkata. After that the air pollution situation in Kolkata is analyzed from different perspectives. We have tried to maintain a fine balance between our mathematical and graphical analysis, backing it up with established reports wherever possible, and even stumbling upon a contradiction with some previous studies on air pollution in the city. It is to mention here that in some cases the analysis is being limited due to the availability of relevant data, which stopped

us from making a more comprehensive study. Finally, we discuss some of the policies, actions and the inactions of the government in the last few years and the visible effects, if any.

2. Geography and Climate Characteristics of Kolkata:

Kolkata is located in India's eastern part at 22°82'N latitude and 88°20'E longitude. It stretches along the Hooghly River and at points is elevated between 1.5 and 9 metres. Originally, Kolkata was a vast lowland while now is one of the most populated and most polluted cities of the world with high level of Particulate Matters in the atmosphere, creating a major health hazard. (Kolkata Online 2010)

According to the 2001 census report, Kolkata has a population density of 24,760 persons/km2 and is the second most populous city after Mumbai. It covers an area of 1480 sq.km (Census of India 2001). The Sundarbans delta located 154 km south of Kolkata separates the city from the Bay of Bengal. Kolkata is divided in different topographical regions. There are five geographical units: east, west, north, south and central Kolkata. The joined regions include Howrah, Hooghly, North 24 Parganas, South 24 Parganas and Nadia. (Census of India 2001)

Not many cities in the world are located near forests. Kolkata is an exception because there is a dense forest which covers Sundarbans and which is a world heritage site. The Sunderbans is home to large numbers of flora and fauna, as well as a place for touristic visits. It offers a source of income to the rural population, as well to the government for its importance in tourism (Kolkata online 2010).

In terms of climate, Kolkata is in the tropic zone i.e. the climate is tropical. During the summer season the climate is very hot and humid. The annual mean temperature during this period is 26.8 °C and the monthly mean temperature ranges from 19 °C to 30 °C. The maximum temperature in Kolkata during the summer (from April to June) exceeds 40°C and the minimum during winter (from December to January) is 12°C. The highest recorded temperature is 43°C and the lowest is 5°C (Kolkata online 2010). Figure-1 shows the average monthly temperature of Kolkata.

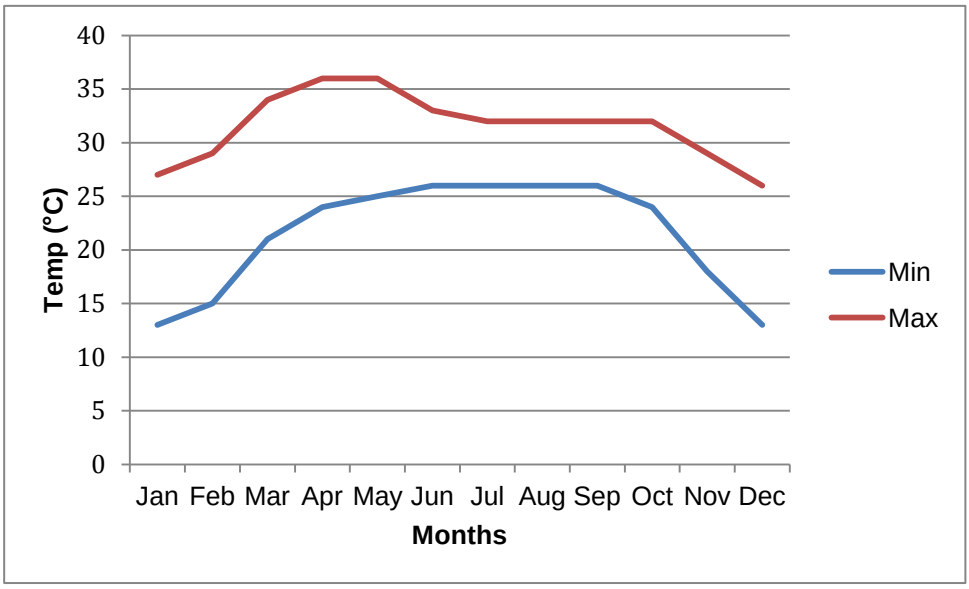


Figure-1: Average Monthly Temperature of Kolkata (Source: BBC 2010)

Between July and October, the city is exposed to the southern monsoon during which heavy rains occur and this is the season when the city gets most of the annual rainfall. Monsoon is an annual weather cycle. In Indian context, it is a seasonally reversing of wind system characterized by wet summers and dry winters. The winds travelling over the Indian ocean towards the north to the subcontinent during the summer monsoon are associated with large scale cyclonic activity and causes wide spread rain for about four months. The monsoon onset starts from middle of June and stays until middle of September (Guha and Biswas 2008). The highest rainfall happens in August (328 mm) to about 114 mm in October when the monsoon retreats (Figure-2). Winter rainfall is very rare and January is the coldest moth (11 C). In general, the weather in Kolkata is hot and the city gets flooded during the rainy season (BBC 2010).

The city has a tropical savannah climate with a distinct monsoon season. The average relative humidity is 66% in winter and 69% in summer. The season before and during monsson are marked by strong south-westerly winds with very high probability of air ventilation (UNEP/WHO, 1992). Being located in a coastal area and influenced by strong sea-based disturbances, Kolkata experiences an average wind speed of 7 km/h throughout the year. The wind direction is mainly southeast and southwest (Gupta et al 2008). The average value of solar radiation recorded is 1428 W/m2 (Gupta et al 2006.).

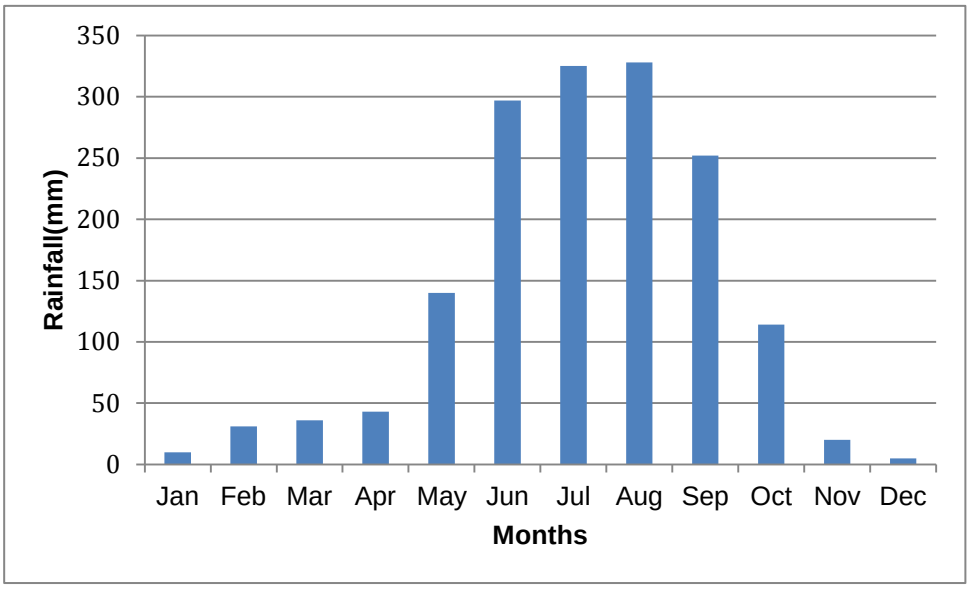


Figure-2: Average Monthly Rainfall of Kolkata (Data Source: BBC 2010)

3. Affects of Air Pollution:

The impact of atmospheric particles has been known since 1980 and they range from mild respiratory infections, through asthma, pneumonia and cardiovascular conditions to death (Gupta et al.2006). The effects can be long-term or short-term. Not all individuals experience polluted air the same way. However, the end result depends on the duration of the exposure, as well as on the dose received. Short-term cases may include, but are not limited to nose and eye itching, nose and throat irritation, headaches, allergic reactions, nausea and some milder upper respiratory infections. The long-term ones are the more serious ones such as lung cancer, heart disease, also brain damage, especially in children, kidney and liver damage, especially in elderly people and the air pollution may further complicate an already existing medical condition (LBNL 2010, Dockery and Pope 1994, Koken et al 2003)

Air pollution is a major problem in urban areas. In many densely populated areas in India the annual concentration of NOx is almost double the maximum allowed concentration of 60 micrograms per cubic meter, with special emphasis during the winter months when elderly people are more severely affected and officials admit this (Bhattacharjee 2010). NO_2 is created from automobile exhaust

and industrial activity which causes allergic asthmatics by augmenting allergic responses (Steinberg *et al* 1991). Similarly SO_2 affects Pulmonary function and cause inflammation of bronchial mucous (Giuseppe and Francesco, 1993).

Kolkata is placed among the most air polluted cities in the world with respect to SPM. In the analysis of the air pollution data of city, we also found that the concentration of SPM is much higher than the other pollutants. Much of the pollution, which was discussed in the earlier sections, is due to the economic and industrial development of the city and the appearance of versatile industries, such as the paper and pulp, organic and inorganic chemical industry, plastic, rubber, iron and textile industries, power plants. The basic reason for such bad air conditions is the high level of SPM of which around 50% originates from transport and about 48% from industries. The main source of industry - originated air pollution is the cluster of industries that use coal combustion to operate (Chakraborty and Bhattacharya 2001). A study conducted by Karar *et al* (2006) during November 2008 to 2009 in two different locations in Kolkata also shows the high concentration of SPM like Lead, Cadmium, Manganese and Iron especially in winter season. These particles can result on severe health threat for the local people (Karen and Michak, 1991; Karar *et al* 2006)

Ghose's study (2009) on health effects due to chronic exposure to air pollution in Kolkata showed a strong link between air pollution and pulmonary, hematologic, immune system, and genotoxic changes that can lead to a number of diseases, such as respiratory illness, cardiovascular problems, and cancer (Ghose 2009). Another study done in Kolkata between 1996 and 2001 which proved that the lung condition of an average citizen of Kolkata is about 7 times more troubled than of the ones living in rural areas due to air pollution. About 47% of the population of Kolkata suffers from lower respiratory tract infections. Some studies show that in the 1990s in Kolkata more than 10.000 deaths occurred due to SPM. SPM with a diameter of less than 10 micrometers (PM10) is too small to be filtered by the natural protective mechanisms of the human respiratory system (Ghose 2009). These pollutants can cause allergic reactions in the respiratory system upon inhalation, such as allergic rhinits, topic dermises and asthma (Fernandes 1995; Arruda *et al* 1992).

Apart from health implications, they also affect visibility and damage infrastructure and recent studies show that suspended particulate matter severely affects human health (Bosco *et al* 2005).

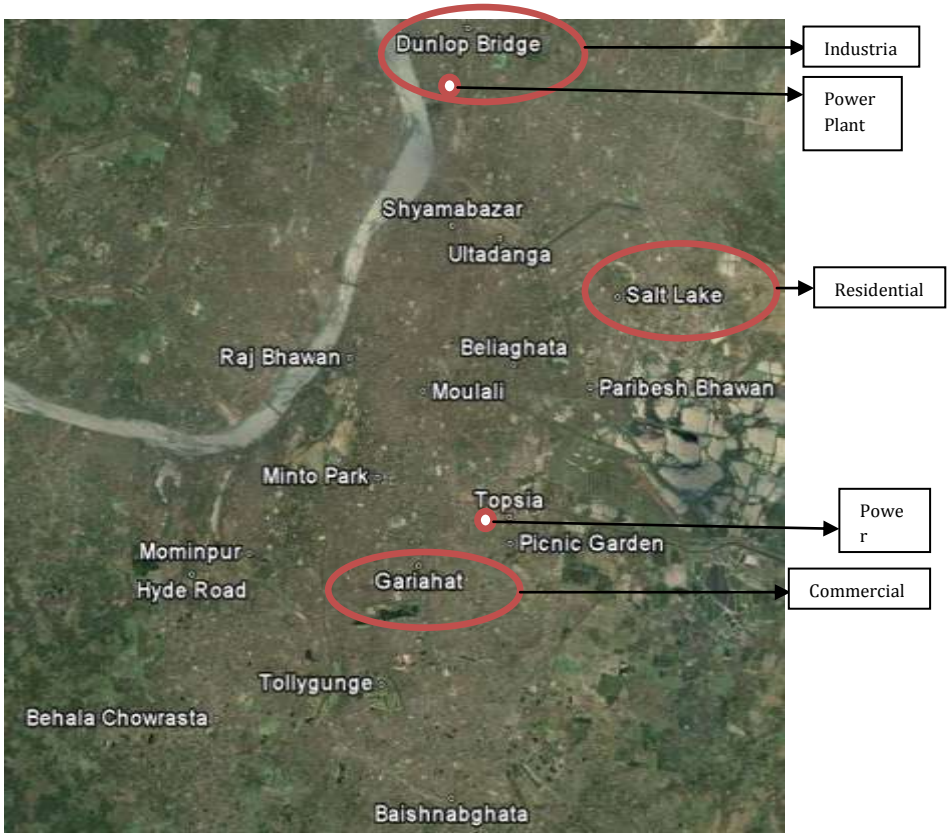
4. Analysis of the Air pollution data:

The following sections will put a light on the air pollution of the city of Kolkata from different perspective. As mentioned the main pollutant considered for this analysis are SO_2, NO2 and SPM. Several studies showed that these are the main pollutants in the city and for this; we considered these pollutants for detailed analysis.

4.4 Level of pollution in different areas:

Kolkata is a large city and its sheer size makes it an interesting study to analyse the air pollution levels at the various parts of the city. In this section, we will show the difference in pollution level at three different parts, namely, the residential, commercial and the partly industrial part of the city. Out of the 17 stations available to us, we have limited our study to only one station for each of the three mentioned areas. This is because only these three stations can be the best representative of the three areas in concern. For this analysis, we are working with the data for the fiscal year 2004-05 (Apr 04-Mar 05), obtained from a statistical database site on India (India Stat 2010).

We choose the relatively newly developed residential area –Salt Lake, an old and vibrant commercial area –Gariahat and a partly industrial area on the outskirts of the city –Dunlop Bridge. Dunlop Bridge was particularly selected because of its close proximity to one of the three thermal power plants of the city, located at Cossipore. Map-1 below displays the areas we have selected along with location of the two power plants in the city.



Map-1: Location of Selected Area for Study (Created Using Google Earth)

The following figure-3 shows the level of SPM at the three areas in question. Kolkata is most affected by suspended particulate matter (SPM), as expected in a mega city, which pose a serious threat to its citizens (Bosco et al 2005).

The figure shows us two distinct trends. First of all, as expected the level of SPM at the residential area is the minimum while that of the industrial area is the highest, the only exception being March 2005, when the level at the commercial area exceeds that of the industrial area. Secondly, the level of the pollutant follows a cyclic pattern across a year, which will be further discussed in details in the following sections.

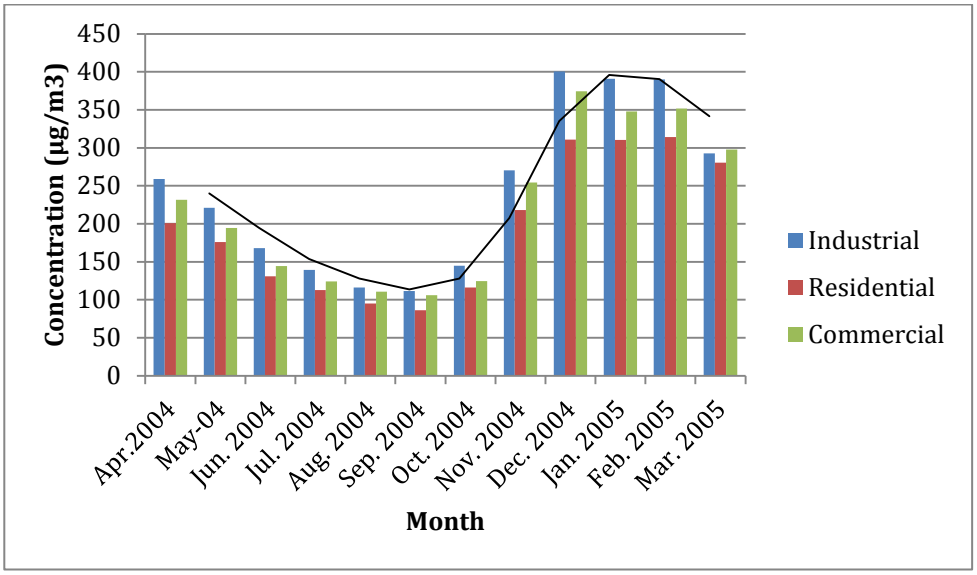


Figure-3: Level of SPM in Different Areas (Data Source: India Stat 2010)

According to the National Ambient Air Quality Standards (NAAQS) of India, the PM10 concentration is 200microgram/m3. In our analysis, we found the monthly average at the three places to exceed that standard in six of the twelve months that we have taken into account, with the levels reaching alarming heights during Nov-Feb. The high level of SPM is due to re-suspension of road dust, soil dust, constructional activities, vehicular traffic, and industrial emissions in the industrial areas. Apart from anthropogenic sources, sources roughness and meteorological conditions also play a part. High relative humidity in Kolkata affects the SPM concentration as it favours gas-to-particle conversion processes (Gupta *et al* 2008). (Karar *et al* 2006) suggests that apart from local emission sources, trans-boundary sources, presumably the nearby power plants, are also responsible for the high SPM level in the city.

The following figure-4 and figure-5 show the level of SO_2 and NO_2 for the three areas. It can be clearly observed that the concentration of SO_2 is much lower relative to NO_2 concentrations. We must note that the level of SO_2 is well within the NAAQS standard of 80 microgram/m3, unlike the level of NO_2, which also has a standard of 80 microgram/m3. The main sources of NO_2 in Kolkata is automobile exhausts and different industrial pollutants (Samanta *et al* 1998). According to Anon (1996) around 4500 new vehicles added in the city traffic each month and it

is increasing every year. As, the amount road space is constricted and due to unplanned traffic management normal vehicular movement is restricted, it increases the fuel consumption and exhaust emission which lead to NO_2 concentration. (Wijetleke and Krunatune 1995). Aneja *et al* (2001) also concluded that the high level of NO_2 concentration in Kolkata can be attributed to the heavy vehicular traffic in the city. (Mondal et al 2000) conducted a study at 19 traffic intersection points in Kolkata and observed similar results, along with significant seasonal variations. Other sources of NO_2 include industrial emissions and burning of fossil fuels. On the other hand, point sources such as power plants and industries have relatively high SO_2 concentration (Aneja *et al* 2001).

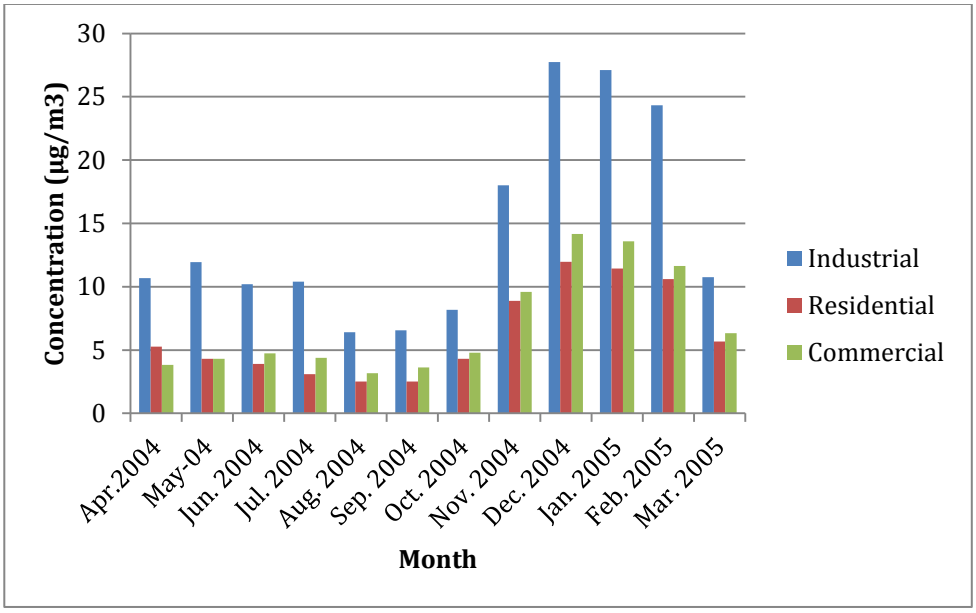


Figure-4: Level of SO_2 in Different Areas (Source: India Stat 2010)

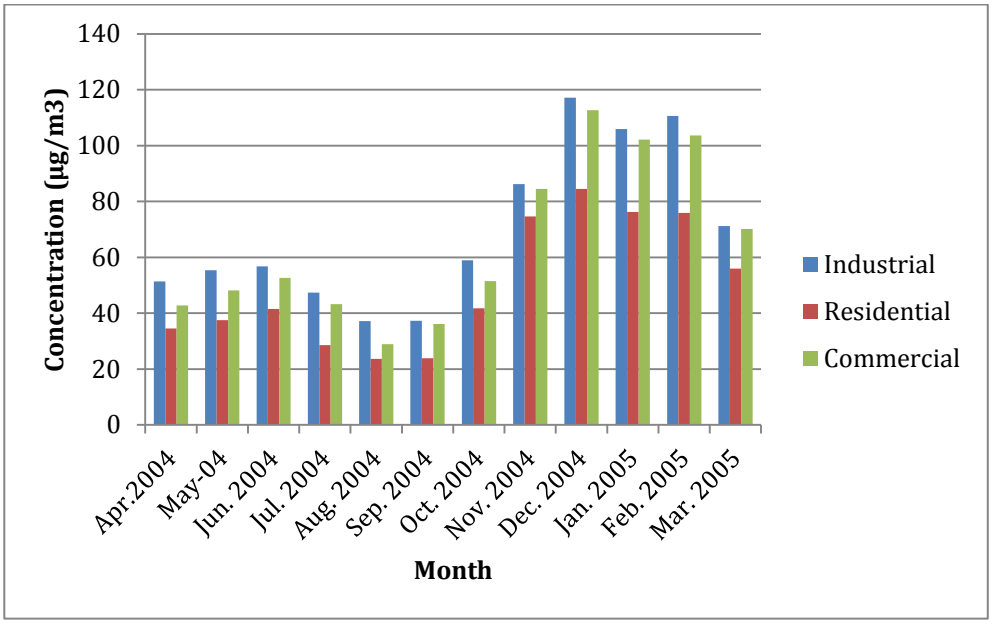


Figure-5: Level of NO_2 in Different Areas (Source: India Stat 2010)

We find similar trends, like those of the SPM levels, when we observe the graphs for these pollutants. What is striking though is the proportion of SO_2 at the industrial area, when compared to the other pollutants. The table-1 below shows the proportions of the annual average SPM, SO_2 and NO_2 when compared to that of the levels found in the residential area.

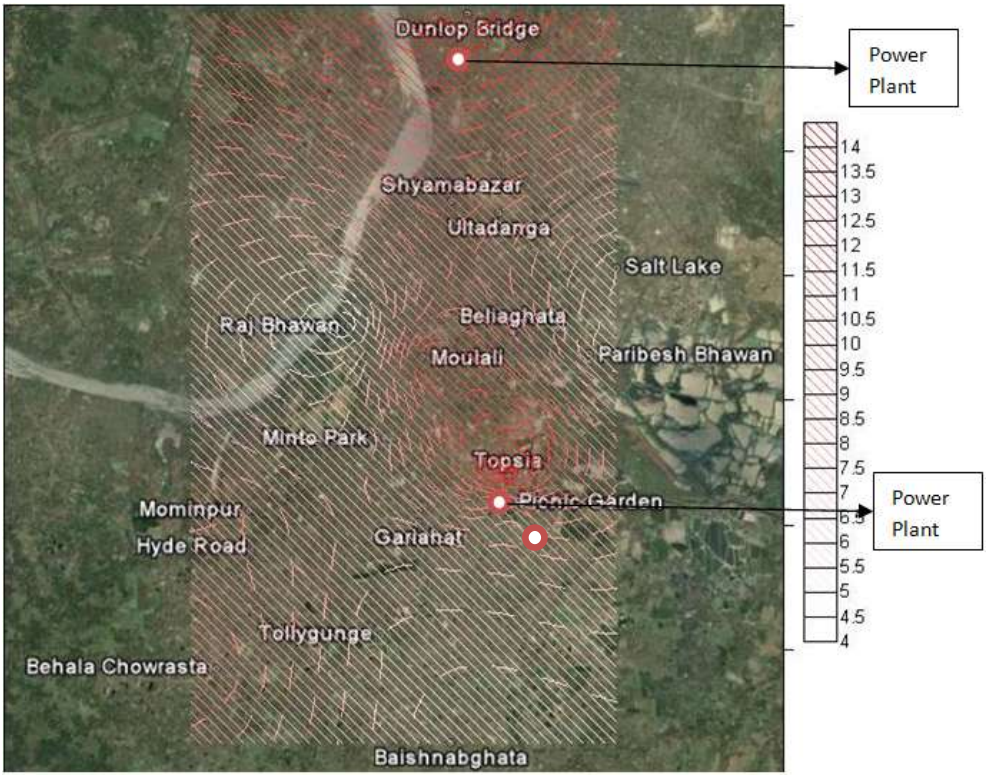
Table-1: Proportion of Pollutants Compare to the Residential Area

	SPM	**SO_2**	**NO_2**
Residential Area	1	1	1
Commercial Area	1.132238	1.129734	1.297115
Industrial Area	1.234968	2.314128	1.395329

The level of SO2 at the industrial site is twice that of the residential site. This is because of emissions from power plants, industrial boilers, and heating and cooking sources (Gupta et al 2008).

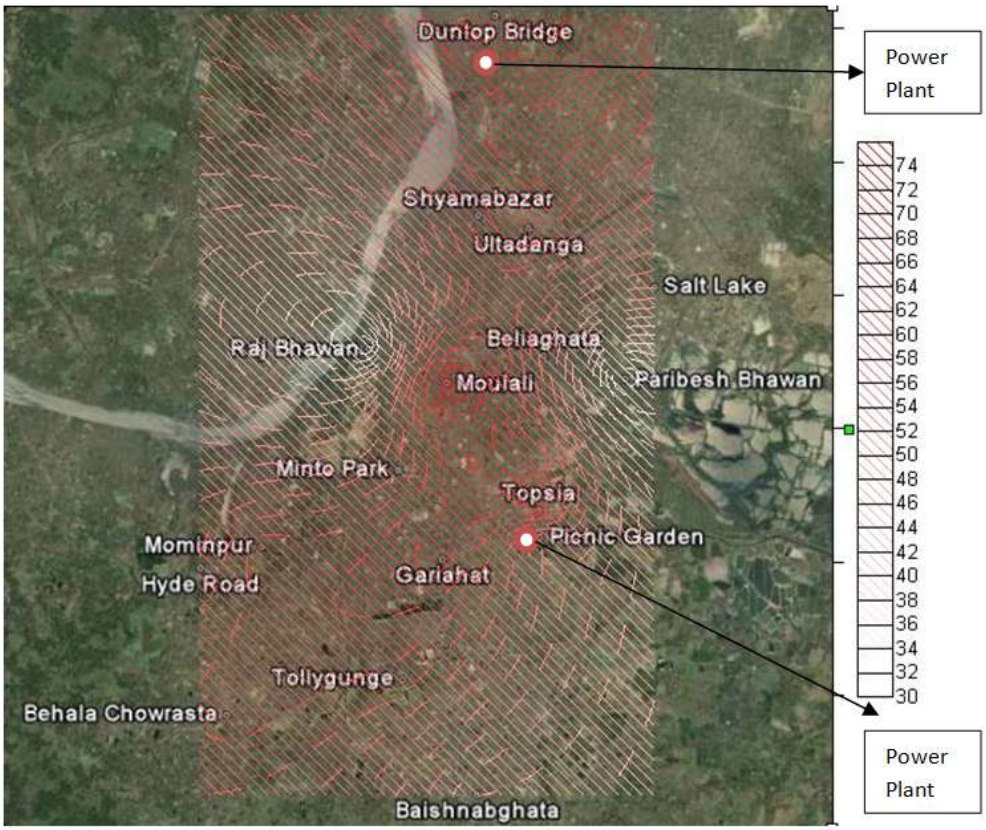
In order to show the level of pollution in different location more visually a contour map is created for different pollutant which are shown in Map 2 to 4. For this the data of all the 17 available station is taken and contour map is created for SO2, NO2 and SPM.

Map-2 shows the SO2 concentration around Kolkata. It can be observed that the level of SO2 is not as high compare to the other pollutants. As mentioned earlier it is below the NAAQS standard in all the areas. However, the around the two thermal power plants the concentration is a bit high compare to the other locations.



(Data Source: India Stat 2010)

Map-2: Level of SO_2 (µg/m3) in Different Location in Kolkata

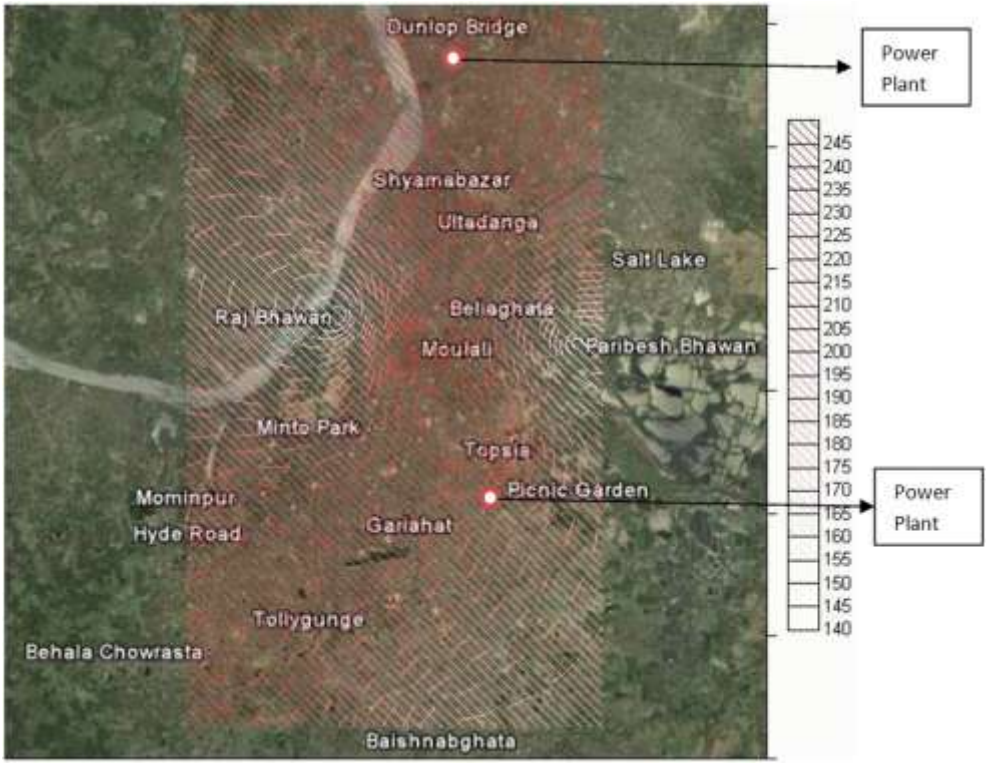


(Data Source: India Stat 2010)

Map-3: Level of NO2 (µg/m3) in Different Location in Kolkata

Map-3 shows the NO2 concentration in Kolkata. As seen, the concentration is quite low in the residential area close to Raj Bhawan, Paribesh Bawan and Salt Lake. But if we look at the main commercial areas like Gariahat, Topsia, Moulali and Dunlop Bridge the level goes up. This can be attributed to the heavy traffic in those areas, throughout the week, which often results in endless traffic jams thereby increasing the concentration in those areas.

Similar trend can be followed for the level of SPM concentration (Map-4). The residential areas mentioned still in a good shape but in the commercial and industrial zones the level of SPM going over the NAAQS standard.



(Data Source: India Stat 2010)

Map-4: Level of SPM (µg/m3) in Different Location in Kolkata

4.2 Seasonal Variation of Pollutants:

The seasonal variation in the climate has a significant relation with the level of pollutants in a city. In this section, we will do a detailed analysis of the cyclic pattern of the levels of the gaseous pollutants, which we observed in the previous section.

Kolkata has three distinct seasons –winter, summer and monsoons. Winter is from Nov to Feb, summer from March to June and finally monsoons from July till October. Studies conducted on the meteorological conditions of Kolkata suggest that during winter the air mass is more stagnant compared to other seasons, as there is less atmospheric circulation and an increase in atmospheric stability. (Gupta *et al* 2008). On the other hand, during summer, there is an increased circulation of air in the troposphere. Also, (Gupta *et al* 2006.) shows that the season before the

monsoon, as well as the monsoon season are dominated by strong winds with greatest potential for air ventilation.

The following figures 6 to 8 show the concentration of the pollutants in the three different seasons.

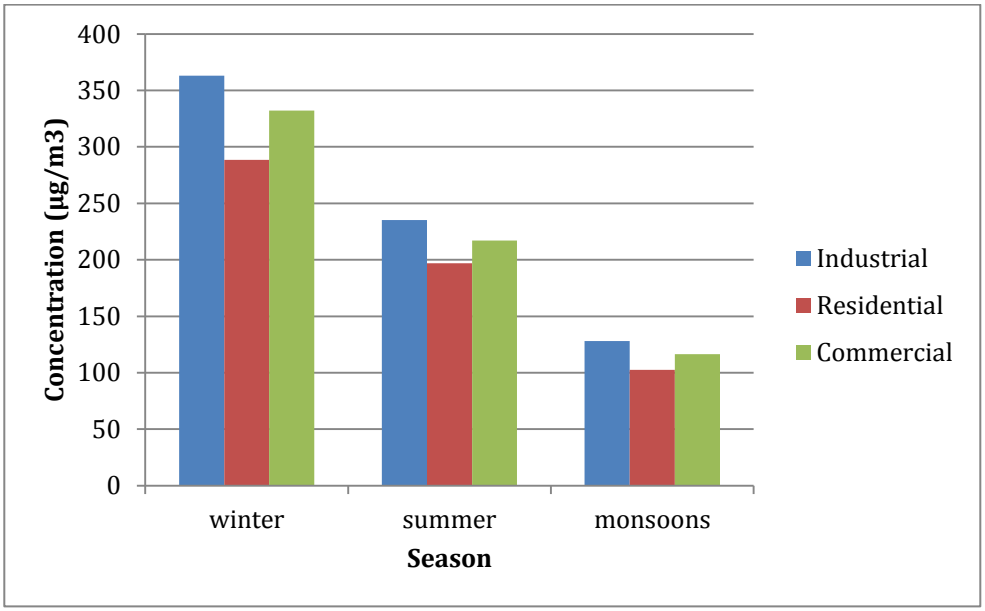


Figure-6: Seasonal Variations of SPM (Data Source: India Stat 2010)

From the figure 6 to 8, we can clearly see that the concentration of the gaseous pollutants are a minimum during the monsoon seasons. Apart from the wind conditions and temperature, the amount of precipitation also plays a vital role to determine the concentration of gaseous pollutants in the atmosphere, due to the cleansing mechanisms associated with it. From figure 2, it must be noted that during winter, Kolkata experiences little or no rainfall. The table below shows the proportions of the pollutants in the different seasons when compares to the monsoon season. SO_2

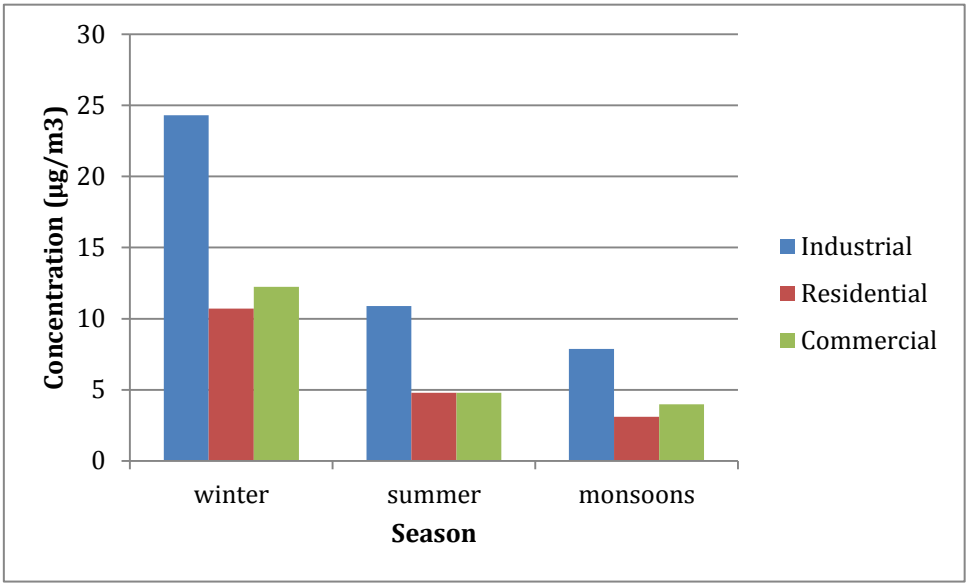


Figure-7: Seasonal Variations of SO_2 (Data Source: India Stat 2010)

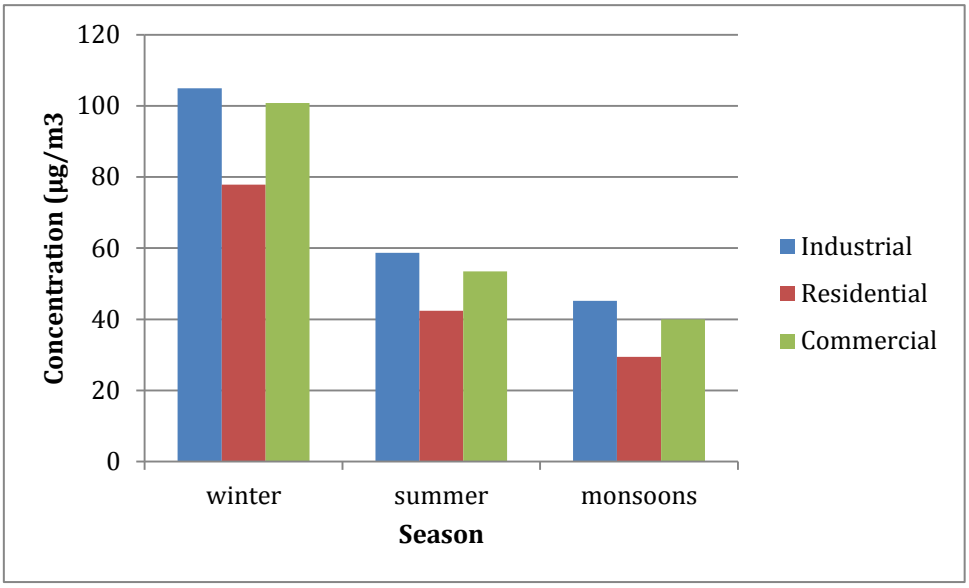


Figure-8: Seasonal Variations of NO_2 (Data Source: India Stat 2010)

It is interesting to observe that the average amount of SO_2 in Kolkata during winter is three times that of monsoons. Apart from the meteorological factors, this can also be attributed to the use of enormous amounts of heating fuels in Kolkata during winter (Lee et al., 1999).

Table-2 Proportion of Pollutants Compare to the Monsoon Season

Seasons	**SPM**	**SO2**	**NO_2**
Winter	2.833922	3.155734	2.475531
Summer	1.871038	1.367384	1.348889
Monsoons	1	1	1

4.3 Relation between the pollutants and Meteorological Factors:

Proper measurement of meteorological parameters is always being a major requirement to understand the type and nature of the atmosphere (Seaman 2003). The chemical properties of the pollutants in the atmosphere depend upon temperature, wind direction, rainfall and relative humidity of a particular location (Elminir 2005).

From the previous sections, the seasonal variation in the level of the pollutants has been well established. We have also noted that this is mainly due to meteorological factors. In this section, we will further establish the relationship between the two. Temperature, wind speed, precipitation and relative humidity are the main meteorological conditions affecting the level of the pollutants in Kolkata.

In order to prove the hypothesis, we decided to conduct the Spearman's Rank Correlation between the average monthly temperature, wind speed, precipitation and relative humidity with the average monthly level of SPM, NO2 and SO2, for the city of Kolkata. Please note that the exact data for temperature, wind speed and precipitation for the period Dec 2004-March 2005 was not available, and hence, for those four months we used the data for Dec 2003-March 2004, as a substitute. We believe that this will not change our results significantly in our endeavour to establish the trend. The table 3 below show the data that we have used, followed by table 4 that shows the ranking of the data, which is a requisite to conduct the

Spearman's Rank Correlation. The relationship between wind speed, rainfall, temperature and relative humidity and the air pollutants in calculated using SPSS package (SPSS 2003).

The results from the Spearman's rank correlation (table-5) make the entire picture very clear. As we can see, the relationship between precipitation and the various air pollutants reveal a strong inverse correlation. The relationship between the other meterological factors and pollutants, although not as strong, does reveal a significant inverse correlation. The following table shows some other studies that conducted similar analysis and the results they obtained. Our conclusions are more or less in agreement with their results.

Table-3 Data for Spearman Rank Correlation

Month	***Pollutants (µg/m3)***			***Month***	***Meteorological Factors***			
	SO2	NO_2	SPM		Wind Speed (km/h)	Rainfall (mm)	Temperature (°C)	Relative Humidity (%)
Apr-04	5.12	39.53	209.65	Apr-04	4.7	60	32.9	78.5
May-04	4.97	42.29	182.93	May-04	4.8	10	39.1	75
Jun-04	4.79	45.22	133.79	Jun-04	4.3	178	32.4	81.5
Jul-04	4.66	38.72	119.83	Jul-04	4.7	301	28.8	87
Aug-04	3.41	29.74	104.59	Aug-04	1.8	392	27.4	94
Sep-04	3.32	29.92	98.62	Sep-04	3.6	342	29	82
Oct-04	5.35	45.20	127.26	Oct-04	2.8	363	26.7	82
Nov-04	11.73	73.62	246.22	Nov-04	1.3	0	24.9	79
Dec-04	18.65	95.02	356.32	Dec-03	1.8	10	19.9	79.3
Jan-05	16.10	88.71	329.64	Jan-04	2.1	0	17.2	76
Feb-05	14.76	88.56	328.38	Feb-04	1.8	0	24.2	68.3
Mar-05	6.93	58.17	267.76	Mar-04	3.1	28	27.5	70.8

(Data Source: India Stat 2010 and Gupta et al 2008)

Table-4: Ranking of Pollutants and Meteorological Factors

	Pollutants (µg/m3)			*Month*	*Meteorological Factors*			
Month	SO 2	NO_2	SPM		Wind Speed (km/h)	Rainfal l (mm)	Temper ature (°C)	Relative Humidity (%)
Apr-04	7	9	6	Apr-04	6	2	2	8
May-04	8	8	7	May-04	8	1	1	10
Jun-04	9	6	8	Jun-04	5	4	3	5
Jul-04	10	10	10	Jul-04	4	2	5	2
Aug-04	11	12	11	Aug-04	1	9	7	1
Sep-04	12	11	12	Sep-04	3	5	4	3
Oct-04	6	7	9	Oct-04	2	7	8	4
Nov-04	4	4	5	Nov-04	10	12	9	7
Dec-04	1	1	1	Dec-03	8	9	11	6
Jan-05	2	2	2	Jan-04	10	8	12	9
Feb-05	3	3	3	Feb-04	10	9	10	12
Mar-05	5	5	4	Mar-04	7	6	6	11

(Data Source: India Stat 2010 and *Gupta et al* 2008)

The literature review from Gupta *et al* (2008), Seaman (2003) and Elminir (2005) on the relationship between meteorological conditions and concentration of pollutants in the city of Kolkata suggests the following:

- The increase in temperature results in an increase in the average mixing height thereby, increasing the volume of air circulation and reducing the concentration of pollutants.

Table-5 Spearman Rank Correlation Results

	Meteorological Factors			
Pollutant	Total Rainfall (mm)	Wind Speed (km/h)	Temperature	Relative Humidity
SO_2	-0.78*	-0.53***	-0.73*	-0.64**
NO_2	-0.80*	-0.49***	-0.69**	-0.62**
SPM	-0.85*	-0.39	-0.58**	-0.75*

*Correlation is significant at the 0.01 level (2-tailed).

** Correlation is significant at the 0.05 level (2-tailed).

*** Correlation is significant at the 0.1 level (2-tailed).

- The increase in wind circulation, due to the nearby Bay of Bengal, reduces the concentration of the gaseous pollutants, with the aid of strong convection currents and increased sea breeze ventilation.
- An increase in the amount of precipitation results in the wash out of the pollutants from the atmosphere, in the form of wet deposition.

An increase in the amount of precipitation results in the wash out of the pollutants from the atmosphere, in the form of wet deposition.

4.4 Differences in Weekdays and Weekends:

Several studies conducted in the USA, (Jo and Park, 2005; Chinkin et al., 2003; Pun and Seigneur, 2003) shows that there is a significant difference in the level of pollutants between weekdays and weekends. All these studies, show that the level of emissions on weekdays is significantly higher than that of weekends. A study conducted in 2005 on this aspect in Kolkata itself, verified that the level of air pollutants is much lower on weekends as opposed to weekdays (Gupta *et al* 2008). In all these studies, this observation could be well-explained as the general perception is that the less industrial activity, along with lower vehicular traffic, ensures lower anthropogenic emissions on weekends.

We decided to conduct a similar study to further verify this phenomenon for Kolkata. However, the results turned out to be significantly different!

For this purpose, we worked with latest available data. We downloaded the daily average level of concentration of SPM, NO_2 and SO_2 from the official website of the Pollution Control Board (known as West Bengal Pollution Control Board) for the city of Kolkata, for the period of Feb 2009 to Jan 2010. Then we calculated the average level of gaseous pollutants on the weekdays as well as the weekends. (the results are shown in table-6) Our result is in contrary to the previous studies and also the established perception.

Table-6: Average Pollutants in Weekdays and Weekends

Day	*Pollutants (µg/m3)*		
	SPM	**SO_2**	**NO_2**
weekdays	185.62	7.20	61.65
Weekends	197.90	7.30	62.81

(Data Source: West Bengal Pollution Control Board 2010)

We feel this is an interesting result and has much scope for further research. A variety of socio-economic conditions could be responsible for this phenomenon. A research could throw some light on the changing lifestyle behaviour of the urban residents of Kolkata in particular, and rising urban middle-class Indians in general.

4.5 Change in Pollution Level

In this section, we wanted to show how the level of pollutants in Kolkata has changed has changed over a period of five years in Kolkata. For this analysis, we took data across two time periods –Fiscal years 2004-05 and 2008-09. As can be seen from figure-9, there is little or no change between the air pollution levels in Kolkata over a span of four years!

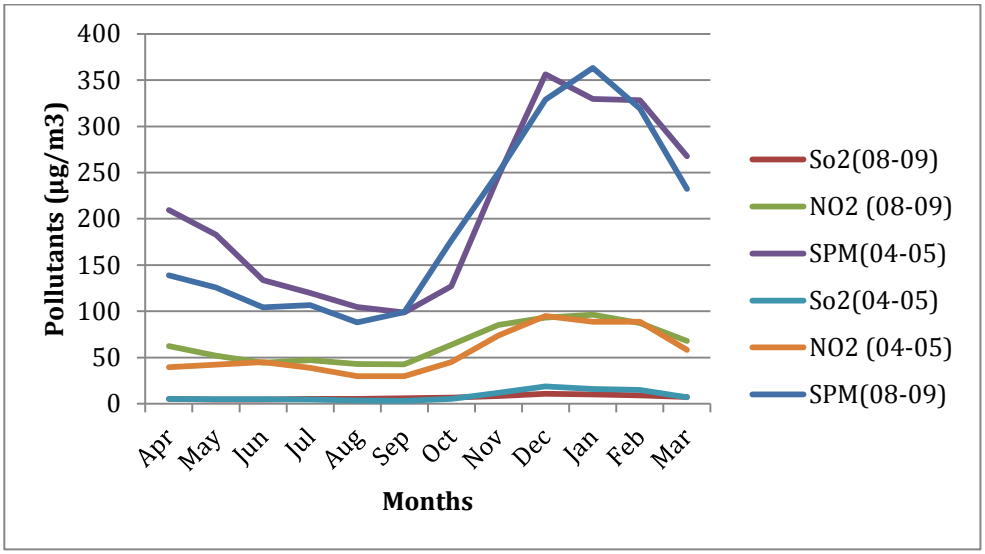


Figure-9: Change in Pollution Level (Data Source: West Bengal Pollution Control Board 2010 and India Stat 2010)

4.6 Air pollution during the festivals:

Durga Puja and Kali Puja (Diwali) are major, very popular and eagerly awaited annual festivals in India, also known as "Festival of Lights. They take place when the season approaches to winter and the climate changes from hot, wet, humid, and windy to colder weather with less wind (October/November). The air pollutants in Kolkata are in their highest concentration during the wintertime. During these festivals, in addition to the traditional lamps litting, a lot of fireworks, sparkles and crackers are being used. Fireworks are mainly used in urban areas and they mainly contain chemicals such as arsenic, sulfur, manganese, sodium oxalate, aluminum and iron dust powder, potassium. They also release pollutants, like sulfur dioxide (SO_2), carbon dioxide (CO2), carbon monoxide (CO), suspended particles (including particles below 10 µm in diameter, i.e. PM10) (Badarinath *et al* 2009.).

There are many studies done on air pollution during these festivals. A study done in 2005 to measure the air pollution caused by these conscious activities of using fireworks and crackers showed that the air pollution has increased especially in the near proximity of those that were using them. Another study showed that the levels of NOx and SO_2 were much higher than the other days and the total

permissible level of SMP and was higher than the allowed limit (West Bengal Pollution Control Board WBPCB 2004).

In order to check the phenomena we also took the data of different pollutants during the eve of Kali Puja and Diwali in different year there we can see the level of pollutants at those times.

Table-7 Comparison of Air Quality during Kali Puja

Pollutant (µg/m3)	**Kolkata Average**			**Residential Standard**
	2003	2004	2009	
SPM	246	243	406	200
SO_2	15	19	10	80
NO_2	50	77	81	80

Data Source: (WBPCB 2004 and 2010)

Table-8: Comparison of Air Quality during Diwali

Pollutant (µg/m3)	***Kolkata Average***			***Residential Standard***
	2003	2004	2009	
SPM	144	233	261	200
SO_2	11	16	9	80
NO_2	46	74	75	80

Data Source: (WBPCB 2004 and 2010)

The Above table 7 and 8 clearly shows high concentration of SPM during these two festivals and it is much higher then the NAAQS for residential areas. The level of NO_2 is also high but it is still below the tolerance level. The level SPM pollution during these occasions also increasing over the years.

5. Policy and Actions for Air Pollution Control:

Kolkata is making serious efforts to improve air quality. Some of the challenges that faces on the road towards successful policy-making are human migration, coal burning industries, diesel driven vehicles, legislation harmonization and harmonization of databases, standards, researches and methodologies. The management is done on two levels, central (the Ministry of Environment, the WBPCB, the Ministry of Transport and Highways, etc.) and local (Department of Environment and local bodies and authorities). In recent years a number of legal interventions have taken place regarding vehicle emissions, fuel quality, introduction of cleaner fuels and reducing old vehicles which has greatly influenced the overall efforts to improve the air quality in Kolkata (Gairola and Sharma 2005).

There were various awareness campaigns raised, among which was the one when the West Bengal Pollution Control Board (WBPCB) gave publicity to the Supreme Court's decision regarding the use of fireworks only between 6 a.m. and 10 p.m. through a request made to mobile phone network companies to send messages to their users with specific text on raising awareness. Also, in 2004 the WBPCB carried out a large number of inspections at firework manufacturing facilities during October and November (just before the festival season) and seized a large number of prohibited ones. The same happened during the actual festival season. The WBPCB also established a monitoring network for ambient air quality measures of main air pollutants such as SPM, SO_2, NOx and Pb (Chakraborty and Bhattacharya 2004)

Another action to improve the air quality in Kolkata was the conversion of coal-fired boilers to oil fired under the India Canada Environment Facility (ICEF) project where the industries, WBPCB and ICEF were partners. It was introduced as a strict regulation, but the industries were reimbursed 50% of the total costs involved in the needed conversion. The situation in 2004 showed that more than 70% of the industries had undergone this conversion. The overall success of this

action has been estimated to about 90% reduction in total PM emitted from all boilers used in industries (Chakraborty and Bhattacharya 2004).

In 2008 a major decision was taken to improve the air quality in Kolkata. In July 2008 high court ordered to phase out the 2-stroke autos and old commercial vehicles from the street of Kolkata by December 2008. Due to lot of political pressure, the government was forced to push the deadline to July 2009. In another policy, the decision was taken to replace the old vehicles with new CNG (Concentrated Natural Gas) vehicles. So, the implementation took place or started to take place from the beginning of August 2009. To get a picture of the change in the pollution level we decided to take a snapshot of NO_2 concentration (NO_2 is taken because it is one of the main pollutant from these 2-stroke vehicles) of November 2009 and compare it to that of 2008, to see the effects of the ban and it was shown in the following figure-10.

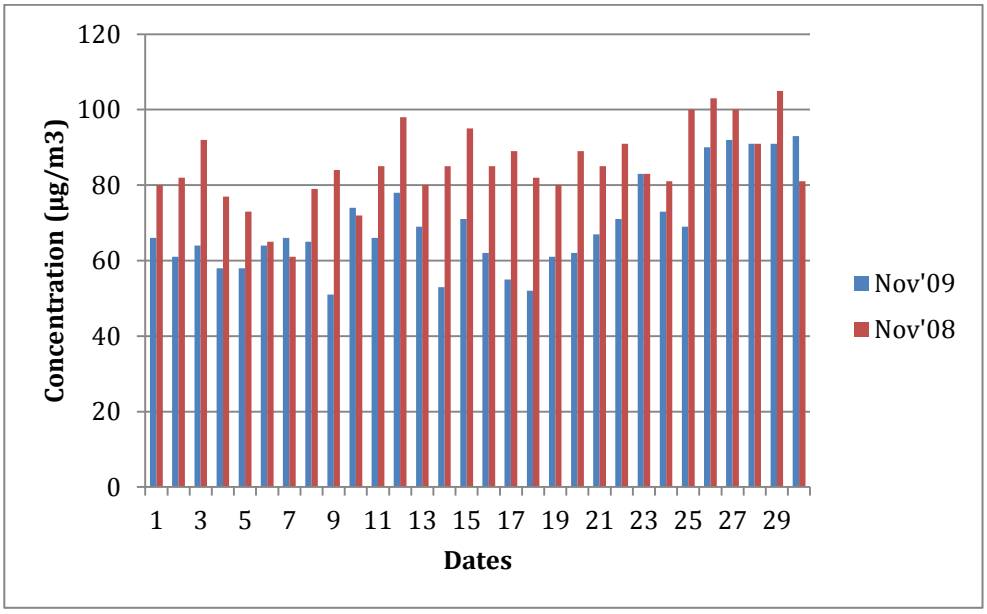


Figure-10: Comparison of NO_2 concentration Between Nov'09 and Nov'08 (Data Source: West Bengal Pollution Control Board 2010)

The figure shows that there is a change in the NO_2 level in Kolkata, with significant reductions during most of the days observed. The policy is now implemented quite well and soon the difference is expected to be much higher.

Overall, Kolkata, alongside with the other major cities of the country has identified many issues that contribute to air pollution and is trying to address all of them. This great challenge should incorporate promoting public transportation, traffic planning and management. However, one has to bear in mind that it is crucial to raise the public awareness so that whatever legislation is introduced is successful (Gairola and Sharma 2005).

Conclusion:

This study aspires to be an introduction to the air pollution situation in Kolkata, marking the various roles of the emission sources, geographical and meteorological features of the city and their interactions. As mentioned before, the availability of data restricts our analysis, but not to a great extent. Effective use of statistical tools and mapping software established the results more prominently, especially the influence of meteorological factors. This study also tries to compare the difference or none between two periods, bringing to light the inefficiency of the various state and non-state actors. A major hindrance for effective implementation of any transport policy in Kolkata is the powerful trade unions, a direct spin-off of the three-decade long communist party rule in the state. These trade unions are politically influential and major vote banks, hence, any policy, like the ban of polluting two-stroke three wheelers, which are detrimental to their interests, will bring them in direct conflict with the implementing body resulting in political dramas. The recent clashes in Kolkata between the police forces and the transport unions bear testimony to this fact. Fortunately, the situation is changing and even though delayed, the ban is being implemented in a phased manner. Our last section tries to capture the results of this policy, in terms of the level of NO_2 for a particular period.

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