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Air Quality Index of ambient air quality of Kolkata Municipal Corporation area in the year 2008-2009

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Software of Air Quality Index calculation of Central Pollution Control Board, Ministry of Environment and Forest, Govt. of India is utilized to express Ambient Air Quality of the Kolkata Municipal Corporation (KMC) area of Kolkata, India in terms of Air Quality Index (AQI) during the period of 2008 to 2009. Monthly 24 h average concentration of ambient air pollutants of PM_{10}, NO_2 and SO_2 monitored by different stations of West Bengal Pollution Control Board, are used in this study. During the periods of April to October and November to March of 2008 to 2009, the AQI values are determined by NO_2 and PM_{10} respectively. Also, PM_{10} and NO_2 values did not attain India's National Ambient Air Quality Standard of 2009 in the period of November to March of 2008-2009. Health impact of the residents of the KMC area in 2008-2009 is assessed from the evaluated AQI data.

Keywords: Ambient air quality, Air Quality Index, health impact, assessed, pollutants, evaluated.

Introduction

Ambient air of an area comprises various substances including air pollutants of Particulate Matter of size less than 10µ (PM_{10}), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). Major sources of NO_2 in ambient air are fossil fuel burning especially vehicular exhaust. Road dust and soil carried by wind contribute PM_{10} in ambient air[4]. SO_2 is entrapped in PM from combustion of sulfur containing oil and coal. Construction and demolition activities and burning of wood generate PM[1]. Considering comparative concentrations as well as pollution potential of different air pollutants, ambient air quality of an area is represented in a single value called Air Quality Index (AQI). Degree of air pollution level is predicted from single value of air quality index instead of concentrations of all major air pollutants.

In this study, Ambient Air Quality of the Kolkata Municipal Corporation area of Kolkata, India during the period of 2008 to 2009, is focused in terms of Air Quality Index and this index is derived by applying software of air quality index calculation of Central Pollution Control Board, Ministry of Environment and Forest, Govt. of India utilizing available concentrations of the three pollutants of PM_{10}, NO_2 and SO_2 in ambient air of this area. Among the three contaminants, one specific substance (either PM_{10} or NO_2) is identified as determining factor in order to select air quality index in respect of its comparative concentration and nature of pollution potential at different times of the study periods. From the evaluated data of this index, assessment is predicted on health impact of residents of the Kolkata Municipal Corporation area during the study periods using range of Air Quality Index values and its health indicators as per Central Pollution Control Board of India. For computation of these air quality indices, monthly 24 h average concentration of ambient air pollutants of PM_{10}, NO_2 and SO_2 were measured by 18 nos. ambient air quality monitoring stations. These monitoring networks were conducted at different locations of Kolkata by West Bengal Pollution Control Board, the environment regulatory agency of West Bengal, India for regular monitoring of ambient air quality.

Methods

During the period of April, 2008 to March, 2009, monthly 24 h average concentrations of PM_{10}, NO_2 and SO_2 were measured by 18 nos. ambient air quality monitoring stations located at different sites of the Kolkata Municipal Corporation area and these monitoring networks were conducted by West Bengal Pollution Control Board, the environment regulatory agency of West Bengal, India[6]. These data are utilized as input to software of AQI calculation of Central Pollution Control Board, Ministry of Environment and Forest, Govt. of India[3].

In Fig. 1, it is illustrated that concentrations of individual pollutants (concentration of PM_{10}:$C_{PM_{10}}$, concentration of NO_2:C_{NO_2}, concentration of SO_2:C_{SO_2}) generate their corresponding sub-indices through equations. These equations are specific in accordance to their concentration levels and hence sub-index ($S.I._{C_i}$) of a pollutant is a function of concentration (C_i) of that pollutant [$S.I._{C_i} = f(C_i)$]. Overall AQI is obtained from maximum value[7] of these sub-indices[3].

During the study period of 2008 to 2009, the values of PM_{10}, NO_2 and SO_2 parameters in the ambient air of KMC area were obtained within the concentration range of 21 $\mu g/m^3$ to 258 $\mu g/m^3$, 19.7 $\mu g/m^3$ to132.5 $\mu g/m^3$ and 2 $\mu g/m^3$ to 16.3 $\mu g/m^3$ respectively. Some model examples are given which are used to calculate all the AQI values of the year 2008 to 2009.

(1) Consider AAQ monitoring station of Raj Bhawan during June, 2008. The PM_{10}, NO_2 and SO_2 concentrations of this location were 41 $\mu g/m^3$, 38.6 $\mu g/m^3$ and 2.3 $\mu g/m^3$ respectively. Three individual sub-indices are calculated below through three respective equations.

Sub-index for PM_{10} ($S.I._{PM_{10}}$) calculation when PM_{10} concentration ($C_{PM_{10}}$) is 41 $\mu g/m^3$

As $C_{PM_{10}} \le 50\ \mu g/m^3$

Then $S.I._{PM_{10}} = C_{PM_{10}} = 41$

Sub-index for NO_2 ($S.I._{NO_2}$) calculation when NO_2 concentration (C_{NO_2}) is 38.6 $\mu g/m^3$

As $C_{NO_2} \le 40\ \mu g/m^3$

Then $S.I._{NO_2} = C_{NO_2} \times \frac{50}{40} = 48.25 = 48$ (approx.).

And $S.I._{NO_2} > C_{NO_2}$.

Sub-index for SO_2 ($S.I._{SO_2}$) calculation when SO_2 concentration (C_{SO_2}) is 2.3 $\mu g/m^3$

As $C_{SO_2} \le 40\ \mu g/m^3$

Then $S.I._{SO_2} = C_{SO_2} \frac{50}{40} = 2.8 = 3$ (approx.).

And $S.I._{SO_2}$ is slightly higher than C_{SO_2}.

$S.I._{NO_2}$ is the maximum among the sub-indices values of 41 ($S.I._{PM_{10}}$), 48 ($S.I._{NO_2}$) and 3 ($S.I._{SO_2}$) and therefore $S.I._{NO_2}$ is selected as overall AQI of Raj Bhawan on June 2008. This AQI is determined from concentration of NO_2 alone though concentration of NO_2 was comparatively lower than that of PM_{10} and concentration of PM_{10} was monitored maximum among the three pollutants at Raj Bhawan area. But apparent observation from comparison of concentrations shows that Raj Bhawan area was polluted more by PM_{10} (higher concentration) than NO_2 (lower concentration) during April 2003. So actual ambient air quality is predicted from AQI value which focuses the composite influence on overall quality of air quality parameters. In this case of comparable concentrations of PM_{10} and NO_2, $S.I._{NO_2}$ is selected as AQI value for these concentration levels of pollutants. Concentrations of both the pollutants were obtained much lower than NAAQS of 2009[2]. It is established from the software that among comparable or same concentration of PM_{10} and NO_2, NO_2 has comparatively higher pollution potential than PM_{10}.

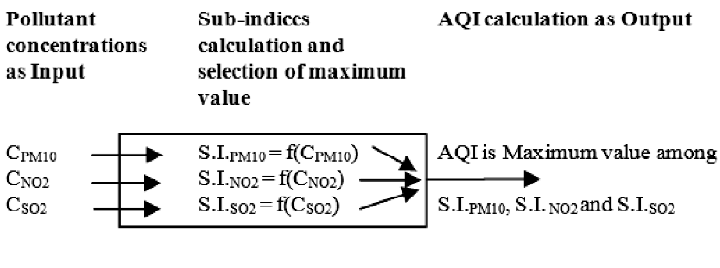

Fig. 1. Formation of sub-index and AQI from corresponding pollutant concentration.

(2) Consider AAQ monitoring station of Behala Chowrasta during October, 2008. The PM_{10}, NO_2 and SO_2 concentrations of that location were 84 $\mu g/m^3$, 77.1 $\mu g/m^3$ and 7.4 $\mu g/m^3$ respectively. The individual sub-indices are calculated below.

Sub-index for PM_{10} ($S.I._{PM_{10}}$) calculation when PM_{10} concentration ($C_{PM_{10}}$) is 84 $\mu g/m^3$

As 50 $\mu g/m^3 < C_{PM_{10}} \leq 100$ $\mu g/m^3$

Then $S.I._{PM_{10}} = C_{PM_{10}} = 84$

Sub-index for NO_2 ($S.I._{NO_2}$) calculation when NO_2 concentration (C_{NO_2}) is 77.1 $\mu g/m^3$

As 40 $\mu g/m^3 < C_{NO_2} \leq 80$ $\mu g/m^3$

$$\text{Then } S.I._{NO_2} = 50 + (C_{NO_2} - 40) \times \frac{50}{40} = 96.37 = 96 \text{ (approx.).}$$

And $S.I._{NO_2} > C_{NO_2}$.

Sub-index for SO_2 ($S.I._{SO_2}$) calculation when SO_2 concentration (C_{SO_2}) is 7.4 $\mu g/m^3$

As $C_{SO_2} \leq 40$ $\mu g/m^3$

$$\text{Then } S.I._{SO_2} = C_{SO_2} \times \frac{50}{40} = 9.25 = 9 \text{ (approx.).}$$

And $S.I._{SO_2}$ is slightly higher than C_{SO_2}.

$S.I._{NO_2}$ is the maximum among the sub-indices values of 84 ($S.I._{PM_{10}}$), 96 ($S.I._{NO_2}$) and 9 ($S.I._{SO_2}$) and $S.I._{NO_2}$ is selected as overall AQI of Behala Chowrasta on October, 2008. This AQI is determined from concentration of NO_2 alone and this case is similar with case no. (1).

(3) Consider AAQ monitoring station of Moulali during November, 2008. The PM_{10}, NO_2 and SO_2 concentrations of that location were 173 $\mu g/m^3$, 114.4 $\mu g/m^3$ and 10.9 $\mu g/m^3$ respectively. All four individual sub-indices are evaluated below.

Sub-index for PM_{10} ($S.I._{PM_{10}}$) calculation when PM_{10} concentration ($C_{PM_{10}}$) is 173 $\mu g/m^3$

As 100 $\mu g/m^3 < C_{PM_{10}} \leq 250$ $\mu g/m^3$

$$\text{Then } S.I._{PM_{10}} = 100 + (C_{PM_{10}} - 100) \times \frac{100}{150} = 148.6 = 149 \text{ (approx.).}$$

And $S.I._{PM_{10}}$ is lower than $C_{PM_{10}}$.

Sub-index for NO_2 ($S.I._{NO_2}$) calculation when NO_2 concentration (C_{NO_2}) is 114.4 $\mu g/m^3$

As 80 $\mu g/m^3 < C_{NO_2} \leq 180$ $\mu g/m^3$

$$\text{Then } S.I._{NO_2} = 100 + (C_{NO_2} - 80) \times \frac{100}{100} = 134.4.$$

And $S.I._{NO_2}$ is higher than C_{NO_2}.

Sub-index for SO_2 ($S.I._{SO_2}$) calculation when SO_2 concentration (C_{SO_2}) is 10.9 $\mu g/m^3$

As $C_{SO_2} \leq 40$ $\mu g/m^3$

$$\text{Then } S.I._{SO_2} = C_{SO_2} \times \frac{50}{40} = 13.6 = 14 \text{ (approx.).}$$

And $S.I._{SO_2} > C_{SO_2}$.

$S.I._{PM_{10}}$ is the maximum among the sub-indices values of 149 ($S.I._{PM_{10}}$), 134 ($S.I._{NO_2}$) and 14 ($S.I._{SO_2}$) and the $S.I._{PM_{10}}$ is selected as overall AQI of Moulali on November, 2008. This AQI value is selected from sub-index of PM_{10} which is determined by its concentration. Concentration of PM_{10} was measured maximum among three parameters and PM_{10} and NO_2 do not attain NAAQS of 2009.

(4) Consider AAQ monitoring station of Moulali during January, 2009. The PM_{10}, NO_2 and SO_2 concentrations of that location were 258 $\mu g/m^3$, 132.5 $\mu g/m^3$ and 13 $\mu g/m^3$ respectively. Three individual sub-indices are calculated below.

Sub-index for PM_{10} ($S.I._{PM_{10}}$) calculation when PM_{10} concentration ($C_{PM_{10}}$) is 258 $\mu g/m^3$

As 250 $\mu g/m^3 < C_{PM_{10}} \leq 350$ $\mu g/m^3$

Then $S.I._{PM_{10}} = 200 + (C_{PM_{10}} - 250) = 208$.

And $S.I._{PM_{10}} < C_{PM_{10}}$.

Sub-index for NO_2 ($S.I._{NO_2}$) calculation when NO_2 concentration (C_{NO_2}) is 132.5 $\mu g/m^3$

As 80 $\mu g/m^3 < C_{NO_2} \leq 180$ $\mu g/m^3$

$$\text{Then } S.I._{NO_2} = 100 + (C_{NO_2} - 80) \times \frac{100}{100} = 152.5.$$

And $S.I._{NO_2}$ is obtained higher than C_{NO_2}.

Sub-index for SO_2 ($S.I._{SO_2}$) calculation when SO_2 concentration (C_{SO_2}) is 13 $\mu g/m^3$

As $C_{SO_2} \leq 40\ \mu g/m^3$

$$\text{Then } S.I._{SO_2} = C_{SO_2} \times \frac{50}{40} = 16.3.$$

And $S.I._{SO_2}$ is calculated slightly higher than C_{SO_2}.

$S.I._{PM_{10}}$ is 135 which has the maximum value among the sub-indices values of 208 ($S.I._{PM_{10}}$), 152.5 ($S.I._{NO_2}$) and 16.3 ($S.I._{SO_2}$). Thus sub-index of PM_{10} is selected as overall AQI of Moulali on January, 2009 and this AQI is determined from concentration of PM_{10}. Among the three concentrations, PM_{10} value was monitored maximum and much higher than either NO_2 or SO_2 value. Concentration of PM_{10} was measured maximum among three parameters and PM_{10} and NO_2 do not attain NAAQS of 2009.

If PM_{10} concentration of ambient air does not exceed 50 $\mu g/m^3$, then corresponding sub-index is evaluated using sub-index calculation of PM_{10} furnished in model example (1). When PM_{10} concentration becomes above 50 $\mu g/m^3$ and does not exceed 100 $\mu g/m^3$, then its sub-index calculation mentioned in model example (2) is applicable. For PM_{10} level within the range from above 100 $\mu g/m^3$ to 250 $\mu g/m^3$, then sub-index calculation of PM_{10} stated in model example (3) is applicable to calculate its corresponding sub-index. If PM_{10} value is obtained in the range from above 250 $\mu g/m^3$ to 350 $\mu g/m^3$, then corresponding sub-index is obtained using its sub-index calculation mentioned in model example (4).

If NO_2 level is monitored in ambient air within the range upto 40 $\mu g/m^3$, then sub-index calculation of NO_2 given in model example (1) is applicable. For NO_2 value ranging from above 40 $\mu g/m^3$ to 80 $\mu g/m^3$, then its sub-index is evaluated using its sub-index calculation given in model example (2). For NO_2 value above 80 $\mu g/m^3$ to 180 $\mu g/m^3$, then sub-index calculation of NO_2 described in model example (3) is applicable.

For SO_2 value in the range upto 40 $\mu g/m^3$, then its sub-index is measured using any of the model examples where its sub-index has been calculated.

During computation of AQI, the interpretation may be carried out that AQI is determined finally by contribution of concentration of any one parameter of PM_{10} and NO_2 for a AAQ monitoring station during a month. If PM_{10} determines AQI, then AQI value becomes equal or less than the concentration value of PM_{10} in air. It is also observed that AQI value generated by either $PM_{2.5}$ or NO_2, becomes greater than monitored concentration value of that parameter in ambient air. Air pollutant SO_2 is not playing role to determine AQI value during the entire study period in the KMC area as its concentration levels were not comparable in comparison to concentrations of PM_{10} and NO_2 and also monitored concentration of SO_2 for the this study period was much lower than NAAQS of 2009.

Results and discussion

Fig. 2 demonstrates monthly variation of PM_{10}, NO_2, SO_2 and AQI values during the year of 2008 to 2009. Overall trends of the four parameters exhibit almost similarity with gradual descending order starting from April to July, then ascending upto maximum value making peak on December or January and finally descending upto March. Therefore, minimum values of most of the parameters were obtained in the month of July and maximum or peak values of these parameters were obtained in the month of either December or January. In few cases, minimum values for some parameters were obtained in the month of June (SO_2 in 2008) or August (PM_{10} in 2008) or September (AQI and NO_2 in 2008).

During the period of 2008 to 2009, PM_{10} values have been compared with prescribed NAAQS of 2009 (100 $\mu g/m^3$) and are found lower and higher in the months from April to October and November to March respectively. The pa-

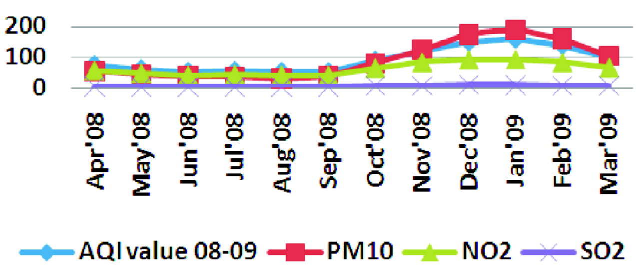

Fig. 2. Monthly variation of AQI, PM_{10}, NO_2 and SO_2 in the KMC area during the period from 2008 to 2009.

rameter NO_2 exhibited attainment of NAAQS (80 $\mu g/m^3$) during April to October of the period 2008 to 2009. NO_2 also attained NAAQS in March 2009. It is further stated that the parameter NO_2 did not attain NAAQS during November to February of 2008 to 2009. During this period, SO_2 level maintained well below NAAQS (80 $\mu g/m^3$).

As the Fig. 2 depict that concentration values of SO_2 were low in comparison to concentration of PM_{10}, $PM_{2.5}$ and NO_2 during this study period and therefore SO_2 does not take part to determine AQI. In the months of April to October for 2008 to 2009 (Fig. 2), the AQI values (53.4 to 90.8) are evaluated higher than PM_{10} values (31.5 $\mu g/m^3$ to 81.9 $\mu g/m^3$) and this finding signifies that AQI values of the said period are determined by parameter NO_2 (42.2 $\mu g/m^3$ to 66 $\mu g/m^3$) as corresponding S.I. values are evaluated lower and higher than the concentration values of PM_{10} and NO_2 respectively as per previous calculations of S.I. values through software. During November to March of the year of 2008 to 2009, range of PM_{10} and NO_2 values were monitored from 104.7 $\mu g/m^3$ to 190 $\mu g/m^3$ and 67.5 $\mu g/m^3$ to 93.3 $\mu g/m^3$ respectively and calculated AQI values are obtained in the range of 102.2 to 160.2. Table 3 focuses range of S.I. values for these ranges of concentrations of PM_{10} and NO_2 and so their corresponding ranges of S.I. values would be about 101 to 200 and 51 to 120 respectively. It is therefore stated that the AQI values during November to March of the year 2008 to 2009 are determined by PM_{10} as its S.I. values are higher than that of NO_2. During the year of 2008 to 2009, AQI values are determined by NO_2 and PM_{10} values for the months of April to October and November to March respectively.

Health effect:

Table 2[3] helps to exhibit different types of health impact for various ranges of AQI values and its health indicators. Different time periods and their corresponding health effect are summarized in Tables 2, 3 and 4. Same range of AQI values from 51 to 100 during April to October for 2008 to 2009 can be attributed to health impact of only minor breathing discomfort of sensitive people in KMC area. The explanation behind this observation of minor or no health impact can be assessed as concentration level of no parameter among PM_{10}, NO_2 and SO_2, had exceeded the NAAQS permissible limit (Table 1)[2] in the ambient air of KMC area during the period from April to October of each of the three periods due to dilution effect of air pollutants in monsoon and summer times[5]. During November to March for 2008 to 2009, same range of AQI values from 101 to 200 is evaluated by

Table 1. National Ambient Air Quality Standards (NAAQS) of India

Pollutants	24 hourly concentration in Ambient Air [$\mu g/m^3$] Promulgated in 2009 Industrial, Residential, Rural and other areas
Sulfur dioxide (SO_2)	80
Oxides of nitrogen as NO_2	80
Respirable Particulate Matter (Size less than 10 μm) or PM_{10}	100

Table 2. AQI Category, range of AQI values and corresponding health effect

Sl.	AQI Category	Range of AQI values	Associated Health Impacts
1.	Good	0–50	Minimal impact
2.	Satisfactory	51–100	May cause minor breathing discomfort to sensitive people
3.	Moderate	101–200	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
4.	Poor	201–300	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure
5.	Very poor	301–400	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
6.	Severe	401–500	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

Table 3. Concentration range of pollutants and their corresponding range of S.I. values

Sl.	Concentration range of pollutant ($\mu g/m^3$)		Range of S.I. value of pollutant
	PM_{10}	NO_2	
1.	0–50	0–40	0–50
2.	51–100	41–80	51–100
3.	101–250	81–180	101–200

Table 4. Period, AQI value and corresponding determining parameter

Sl.	Period	Parameter exceeded NAAQS of 2009	AQI range	Determining parameter of AQI
1.	April 08 to October 08	–	51–100	NO_2
2.	November 08 to March 09	PM_{10}, NO_2	101–200	PM_{10}

software which predicts health impact of breathing discomfort to people with lung disease and discomfort to people with heart disease, children and elders.

Conclusion

AQI is selected from highest value of sub-indices of pollutants derived from their respective concentrations. During the months of April to October for the year of 2008 to 2009, NO_2 is responsible for determination of AQI of KMC area. In these months, the range of AQI values (51–100) can be attributed to effect of minimum breathing discomfort to sensitive people of KMC area. During November to March of 2008 to 2009, AQI values (101 to 200) are derived by PM_{10} as determining parameter and also PM_{10} values did not attain NAAQS of 2009. This range of AQI values (101 to 200) has effect of breathing discomfort to people with lung disease and discomfort to people with heart disease, teen agers and aged persons.

Therefore, NO_2 and PM_{10} are identified as predominant pollutants to determine AQI values during the three study periods. SO_2 values being monitored in the lower side in AAQ of Kolkata, has no effect to determine AQI.

During summer and monsoon times of 2008 to 2009, NO_2 concentrations of Kolkata air determines AQI values, whereas winter time during 2008 to 2009 shows PM_{10} as determining pollutant to evaluate AQI.

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