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Assessment of combined Noise-Air quality and combined exposure to Noise-Air pollution at the curbside open-air microenvironment of Kolkata city, India

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ABSTRACT: A four year long research programme divided into four phases has been designed for the first time to assess the combined Noise-Air quality and combined exposure to Noise-Air pollution at the curbside open-air microenvironment of Kolkata city, India. The results and the findings of the different phases of study had already been published. The objective of the review work is to fuse the findings of the different phases of studies; to identify the factor(s) influences the degree of correlation between concentration of the air pollutant(s) and traffic noise level at the microenvironment of the city. Incidence of moderate to very strong positive Pearson's correlation coefficients between concentration of the air pollutant(s) and traffic noise level indicated chances of correlated exposure to these environmental stressors at the microenvironment of the city. Average combined Noise-Air quality and combined exposure to Noise-Air pollution of the microenvironment of the city was very poor (0.17) to fair (0.50) and poor (-0.06) to excellent (3.33) respectively. The best combined Noise-Air quality and the best level of combined exposure to Noise-Air pollution at the microenvironment of the city was prominently evidenced in after-noon, in summer and under variable road geometry. However, the worst combined Noise-Air quality and the worst level of combined exposure to Noise-Air pollution at the microenvironment of the city was prominently evidenced in evening, in winter and under constant road geometry. A principal component analysis revealed that intensity of wind determines the degree of correlation between the environmental stressors at the microenvironment.

Keywords: combined Noise-Air quality, correlated and combined exposure to Noise-Air pollution, curbside open-air microenvironment, Kolkata city

INTRODICTION

Geography of Kolkata city. Kolkata is the capital city of the Indian state West-Bengal. The city is centered on latitude 22°34′N and longitude 88°24′E. The city is more than three hundred years of old and expands in an unplanned manner and linear orientation on the north-south axis along the bank of the river Hooghly. The core area of the city is generally flat with elevation ranging from 5 m to 6 m above the mean sea level (Gupta *et al.*, 2006). The flatness of topography of the city is frequently hindered in presence of thousands of high-rise buildings. The city is divided into five major geographical regions namely, east, west, north, south and central Kolkata (Spiroska *et al.*, 2011). There is hardly any demarcation of areas of distinct activities e.g., residential, industrial, commercial in most part of the city (Majumdar (neé Som) *et al.*, 2009).

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The city area under the Kolkata Municipal Corporation (KMC) covers an area of 187 km^2. However, the wider urban agglomeration, the Kolkata Metropolitan surrounds the KMC covers an area of 1380 km^2 (Gupta *et al.*, 2006).

The city has the Tropical Savannah climate with a marked monsoon season. Monthly mean temperature ranges from 20 °C to 31 °C and the maximum temperature often exceeds 40°C in summer (UNEP/ WHO, 1992). Average annual rainfall of the city is frequently recorded around 1582 mm (Kar *et al.*, 2010). Monthly mean relative humidity ranges from 66% to 69%. The pre-monsoon and monsoon season is dominated by strong southwesterly winds with greatest air ventilation potential (UNEP/WHO, 1992). Moderate northwesterly winds prevail for rest of the year with high frequency of calms. The city is also located in coastal area of the Bay of Bengal and hence often influenced by sea-based disturbances e.g., cyclone. Average wind speed blowing throughout the year is 7 km/h. Average rate of solar radiation is 1428 W/m^2 (Gupta *et al.*, 2006).

Kolkata is also one of the populous cities of the world. The approximate population of the city is 4.5 million and the population density is of 24760 persons/km^2 (Majumdar *et al.*, 2010).

Ambient air quality of the city. Ambient air quality of Kolkata city has been deteriorated gradually with time because of rapid and unplanned urbanization, population growth, insufficient public facilities and industrialization. The city has been placed among the 41 most polluted cities of the world with respect to the concentration of suspended particulate matter (DOE, 2002). Recent research works carried out on the status of the ambient air quality of the city with respect to concentrations of different air pollutants e.g., respirable particulate matter, oxides of nitrogen and traffic noise level reported frequent violation of the National Ambient Air Quality Standard (NAAQS) prescribed by the Central Pollution Control Board (CPCB) of India (Mondal *et al.*, 2000; Ghose *et al.*, 2004; Karar *et al.*, 2006; Das *et al.*, 2006; Chowdhury *et al.*, 2012). Concentrations of the air pollutants in the city also exhibit a distinct seasonal variation. The concentrations of the air pollutants remain higher in winter probably due to lower winds and lower mixing heights. Whereas, faire air quality are frequently reported during monsoon probably due to higher wind, higher ventilation potential of the atmosphere and wet deposition of the air pollutants from the atmosphere (Mondal *et al.*, 2000; Karar *et al.*, 2006; Gupta *et al.*, 2007; Spiroska *et al.*, 2011). Professionals' as well as commuters' exposure to noise, heat, dust and volatile organic compounds (VOCs) in state transport buses, passenger cars and petrol pumps were also accounted higher in the context of the city (Mukherjee *et al.*, 2003; Som *et al.*, 2007; Majumdar (neé Som) *et al.*, 2008; Sen *et al.*, 2011).

Health burden related to the air quality. Residents of the city frequently suffer from traffic noise related annoyance, hearing loss, deafness (Mukherjee, 1998; Chakraborty *et al.*, 2002) and air pollution related cardiovascular, respiratory and genetic diseases e.g., higher concentration of lead in blood, increase in alveolar macrophage number in the sputum, reduced lung function, metaplasia of air way cells, immune alteration, platelet and leukocyte activation and genotoxic changes (Misra *et al.*, 1994; Lahiri *et al.*, 2000; Ghose, 2009). Studies also indicated that during the 1990s over 10,000 premature deaths per year in the city were caused by suspended particulate matter (Kazimuddin *et al.*, 2000).

Relationship between the air quality and the transport system of the city. There is a keen relationship between ambient air quality and transport system of the city. Higher concentrations of the air pollutants in the ambient atmosphere of Kolkata city are attributed to domestic sources (2%), industrial sources (48%) and automobile exhaust (50%) (Majumdar *et al.*, 2010). Automobile exhaust may contribute up to 80% of the total air pollution load in the city (Ghose, 2009). Auto mobiles are the part of transport system. There are 0.82 million registered vehicles in Kolkata, of which light, medium, heavy and other vehicles constitute 48%, 42%, 7% and 3% respectively. From 1995 to 2002 there was a total growth of 44.5% of registered vehicles and the number of vehicles is projected to about 1.3 million by 2015 (Som *et al.*, 2007). Beside this local vehicles are supplemented with those coming from suburbs. But total land used in Kolkata as road space, another important part of the transport system is only about 6% to 7% instead of the expected value of 25% to 30% (Som *et al.*, 2007; Majumdar *et al.*, 2010). This consequences tremendous vehicular density (5685 cars/km^2) and very low average traffic speed of less than 20 km/h in Kolkata (Majumdar (neé Som) *et al.*, 2008; Dutta *et al.*, 2010).

The ambient air quality of the city is attributed to frequent traffic halt, crawling traffic speed, poor maintenance of vehicles and erratic driving pattern coupled with presence of high-rise buildings, slow wind pattern with higher percentage of calms and high temperature built-up within the city (Gajghate *et al.*, 2005). Instead of traffic volume the noise emission from traffic of the city is mainly attributed to behavior of the drivers and ill maintained engines and silencers of cars (Chowdhury *et al.*, 2012).

Although some recent changes in law regarding the prohibition of older commercial vehicles (Ghose, 2009), and activities like widening of major roads, construction of flyovers, diversion of road, increase of effective space of road by leveling and concretization of tram-ways, and traffic flow diversion at peak hours in and around Kolkata so as to reduce traffic jams and in turn minimize air pollution and noise level (Majumdar *et al.*, 2010). But this is insufficient to counteract the vehicular growth. Projections, therefore consistently show worsening air quality in Kolkata in future (Ghose, 2009).

A new direction to assess urban air quality. In recent years a new school of thought has been developed to assess the urban air quality holistically with respect to air and noise pollution (Chowdhury *et al.*, 2015a). The justifications against the thought are:

- Traffic is a shared source of both air and noise pollution.
- Respiratory, neurobehavioural and cardiovascular diseases have been found to be associated with both traffic related air and noise pollution exposure (Ising *et al.*, 2004; Freire *et al.*, 2010; Gan *et al.*, 2012).
- A moderate positive correlation between concentrations of air pollutant(s) and traffic noise level have been found to be associated with correlated exposure to these environmental stressors and was also found to form confounding in epidemiological studies (Weber, 2009; Allen *et al.*, 2009; Foraster *et al.*, 2011).
- For this reason scientists have suggested an integrated index, the City Noise-Air index to describe the urban air quality in terms of noise and air quality (Silva *et al.*, 2012).
- Scientists also have formulated the Combined Exposure Factor (Vlachokostas *et al.*, 2012) to estimate the quality of combined exposure to noise and air pollution of a city.

Intuitively, combined Noise-Air quality and combined exposure to Noise-Air pollution has never been assessed in the context of Kolkata city. For this reason a four year long research programme (divided into four phases) was designed to assess the combined Noise-Air quality and combined exposure to Noise-Air pollution at curbside open-air microenvironment of Kolkata city.

The justification to concentrate on the microenvironment is attributed to the maximum chances of co-occurrence of higher concentration of air pollutants and traffic noise level due to presence of traffic in the microenvironment. The exposure to noise and air pollution in the microenvironment is also simultaneous and mainly of short-term and occupational. The results and the findings of the different phases of study had already been published. But the objective of the review work is:

- To fuse the findings of the different phases of studies conducted over four years on the combined Noise-Air quality and states of combined exposure to Noise-Air pollution at the curbside open-air microenvironment of Kolkata city, India.
- To identify the factor(s) influences the degree of correlation between concentration of the air pollutant(s) and traffic noise level.
- To conclude the research programme.

MATERIALS AND METHODS

Almost a four year long (November'2009 – May'2013) research programme in a specified study area was planned to assess the Noise-Air quality and states of exposure to Noise-Air pollution at the curbside open-air microenvironment of Kolkata city (Table 1; Fig. 1). The detailed experimental methodology has been described in the research work of Chowdhury *et al.* (2011) and Chowdhury *et al.* (2015b, 2015c and 2015d). To fuse the results of the Phase I and II study with Phase III and IV the raw data generated in the Phase I and Phase II study was averaged respectively as per the methodology described in the research work of Chowdhury *et al.* (2015d) and Chowdhury *et al.* (2015c). Combined Noise-Air quality of the microenvironment of the city was determined in terms of City Noise-Air index proposed by Silva *et al.* (2012) with some significant modifications described in detail in the work of Chowdhury *et al.* (2015c and 2015d). Status of combined exposure to Noise-Air pollution at the microenvironment of the city was determined in terms of Combined Exposure Factor (Vlachokostas *et al.*, 2012) with some significant modifications described in the work of Chowdhury *et al.*, 2015c and 2015d. States of correlated exposure to concentration of air pollutant(s) and traffic noise level were estimated in terms of Pearson's correlation coefficient.

The factor(s) influences the degree of correlation between concentration of the air pollutant(s) and traffic noise level was determined through a Varimax rotated Principal Component Analysis with Kaiser Normalization in SPSS v20 environment. The Principal Component Analysis was performed on the collective data set (N = 254) generated in the four phases of study. The principal component analysis was performed according to the methods described in the manual 'Solving Homework Problems in Data Analysis II, Principal Component Analysis: Validation, Outliers and Reliability'.

RESULTS AND DISCUSSION

States of correlated exposure at the microenvironment of the city. Correlated exposure to traffic noise level and concentration of the air pollutant(s) may be significant when there is at least a moderate positive correlation ($r \geq 0.40$) exists between them (Weber, 2009; Allen *et al.*, 2009; Foraster *et al.*, 2011). In the present study the correlations accounted between concentration of the air pollutant(s) and traffic noise level are presented in the Table 2. The minimum and the maximum of Pearson's correlation accounted between concentration of $PM_{2.5}$ and traffic noise level in the four phases of study was 0.05 and 0.68 (very weak positive and strong positive, Chowdhury *et al.*, 2015a). The minimum and

Table 1. Comprehensive study plan for the research work

Study phase	I	II	III	IV
References	Chowdhury *et al.*, 2011	Chowdhury *et al.*, 2015b	Chowdhury *et al.*, 2015c	Chowdhury *et al.*, 2015d
Performed under	Constant road geometry	Variable road geometry	Relatively constant road geometry in two peaks (day and evening) and non-peak traffic hour	Relatively constant road geometry in Winter and Sumer
Monitoring session (m)	1(including day, after-noon and evening)	1(after-noon)	3 (day; 08:00 a.m. to 12:00 noon, after-noon; 12:00 noon to 04:00 p.m., evening; 04:00 p.m. to 08:00 p.m.)	1 (including day, after-noon and evening)
Times of sampling (f)	12	1	2 (winter and summer data were averaged during analysis)	2 (winter and summer)
Duration of sampling (t)	12 h	4 h	4 h	12 h
Monitoring sites (p)	1 (Jadavpur University)	52 (Fig. 1)	38 (Fig. 1. Sampling point 1-38 excluding 'A' and 'B' sub-stations)	
Sampling frequency = (m×f×t×p) h	144 h	208 h	912 h	
Duration o the study	Nov'2009 to Feb'2010 (in winter)	Mar'2011 to May'2011 (in summer)	Nov'2011 to May'2012 and Nov'2012 to May'2013 (in winter and summer)	
Study area (Fig. 1)	Within four important traffic intersections of south Kolkata (viz., Park Street (22°33′17.23″N, 88°21′50.14″E), Park Circus (22°32′35.82″N, 88°21′58.14″E), Garia (22°27′57.08″N, 88°22′40.10″E) and Tollyguange Tram Depot (22°29′35.10″N, 88°20′43.04″E)			
Variables simultaneously monitored	vehicles/4-h, L_{eq} [dB(A) 8-h-TWA, recommended by OSHA], $PM_{2.5}$ and NO_2 (μg/m^3, 24-h-TWA recommended by CPCB India, 2009), T (°C), RH (%), WS (km/h), RW (m)			
Statistical analysis performed	Minimum, maximum, average, standard deviation, coefficient of variation and Pearson's correlation coefficient			
Combined indexing performed	The City Noise-Air index (Silva *et al.*, 2012) and Combined Exposure Factor (CEF, Vlachokostas *et al.*, 2012)			

vehicles/4-h (total number of motorized vehicles), L_{eq} (equivalent traffic noise level), $PM_{2.5}$ (particulate matters have aerodynamic diameter ≤ 2.5 μm), T (temperature), RH (relative humidity), WS (wind speed), RW (road width)

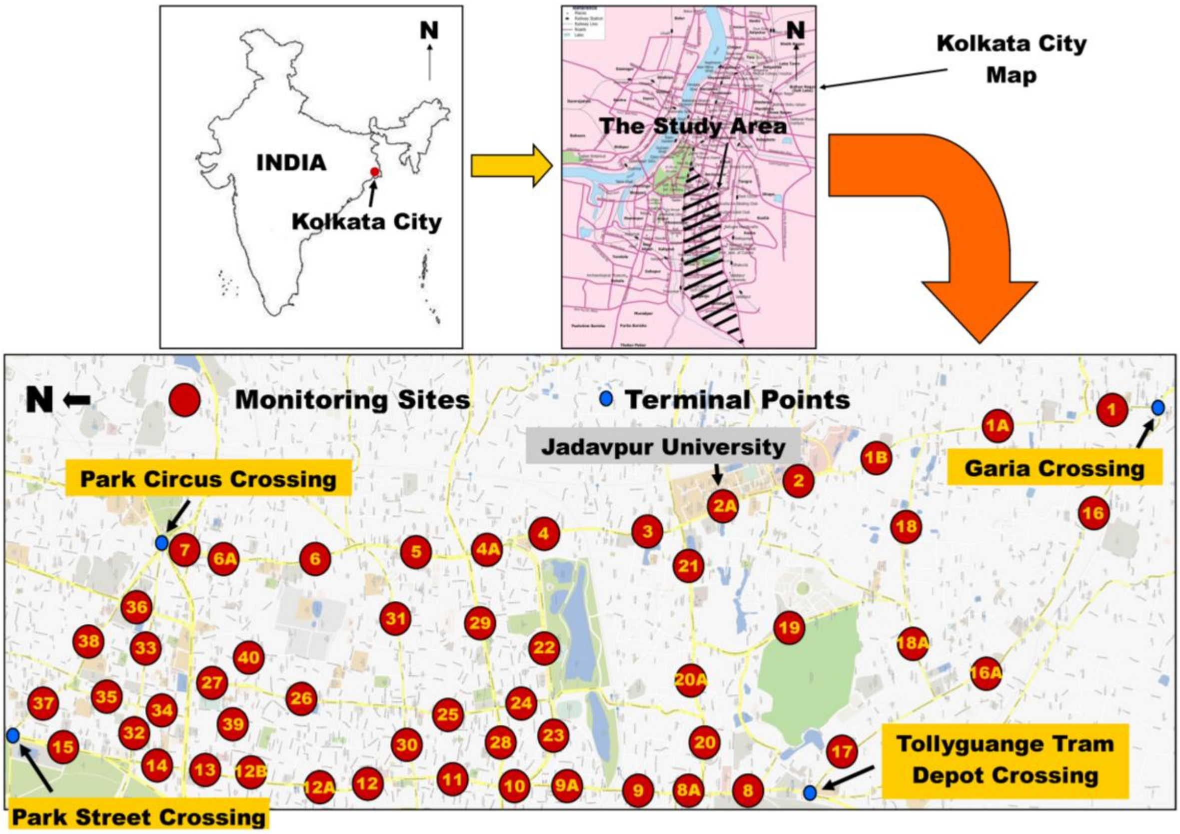

Fig. 1. Diagrammatic representation of the study area and monitoring sites (The map is not to scale)

the maximum of Pearson's correlation accounted between concentration of NO_2 and traffic noise level in the four phases of study was 0.14 and 0.89 (very weak positive and very strong positive). The moderate to very strong positive correlation coefficients between concentration of the air pollutant(s) and traffic noise level indicated chances of correlated exposure to these environmental stressors at the curbside open-air microenvironment of the city. In most of the cases the correlations accounted between the concentration of NO_2 and traffic noise level were higher than the correlation accounted between concentration of $PM_{2.5}$ and traffic noise level which also signified a higher chance of correlated exposure to concentration of NO_2 and traffic noise level than the concentration of $PM_{2.5}$ and traffic noise level at the curbside open-air microenvironment of the city.

Table 2. Correlation between concentration of the air pollutant(s) and traffic noise level

Study Phase	Session/Seasons	Sample size (n)	Correlation (r) between concentration of $PM_{2.5}$ and traffic noise level	Correlation (r) between concentration of NO_2 and traffic noise level
I	Winter	12	0.68^{*}	0.89^{**}
II	After-noon	52	0.43^{**}	0.39^{**}
III	Day	38	0.08	0.14
do	After-noon	38	0.15	0.33^{*}
do	Evening	38	0.09	0.25
IV	Winter	38	0.22	0.24
do	Summer	38	0.05	0.42^{**}

*statistically significant at 0.05 level and **statistically significant at 0.01 level

The inconsistent correlation between concentration of the air pollutant(s) and traffic noise level in the context of the city might be attributed to the fact that air pollutants and noise have different mode of dispersion and/or transportation in the atmosphere. Air pollutants disperse in the atmosphere by diffusion and drift. Thus, its concentration in the atmosphere is extensively dependent on the number of sources, prevailing local meteorological condition e.g., wind speed, wind direction, vertical temperature profile of the atmosphere and background concentration of the pollutants. Noise is transmitted in the atmosphere by pressure waves that can be reflected and refracted and increased through superimposition, but otherwise have a short half-life and lower dependency on the prevailing meteorological condition than air pollutants (Davies *et al.*, 2009).

Combined Noise-Air quality of the curbside open-air microenvironment of the city. The minimum and the maximum of the average City Noise-Air index recorded in the four phases of study was of 0.17 and 0.50 (Table 3). The values of the index signified that combined Noise-Air quality of the microenvironment of the city was very poor to fair. The best combined Noise-Air quality of the microenvironment of the city was prominently evidenced in after-noon, in summer and under variable road geometry. However, the worst combined Noise-Air quality of the microenvironment of the city was prominently evidenced in evening, in winter and under constant road geometry.

Combined exposure to Noise-Air pollution at the microenvironment of the city. The minimum and the maximum of average of the Combined Exposure Factor (CEF) recorded in the four phases of study was of -0.06 and 3.33 (Table 4). The values of the factor signified that the quality of the combined exposure to Noise-Air pollution in the microenvironment of the city was poor to excellent. The best level of combined exposure to Noise-Air pollution in the microenvironment of the city was also prominently evidenced in after-noon, in summer and under variable road geometry. However, the worst combined exposure to Noise-Air pollution in the microenvironment of the city was also prominently evidenced in evening, in winter and under constant road geometry.

Table 3. Average value of the City Noise-Air index

Study Phase	Session/Seasons	Average value of the City Noise-Air index
I	Winter	0.17±0.17
II	After-noon	0.50±0.23
III	Day	0.40±0.24
do	After-noon	0.44±0.22
do	Evening	0.39±0.26
IV	Winter	0.19±0.13
do	Summer	0.20±0.18

Table 4. Average value of the Combined Exposure Factor (CEF)

Study Phase	Session/Seasons	Average value of Combined Exposure Factor (CEF)
I	Winter	-0.06±0.09
II	After-noon	3.33±2.40
III	Day	1.53±0.55
do	After-noon	1.66±0.54
do	Evening	1.38±0.43
IV	Winter	-0.08±0.14
do	Summer	0.35±0.37

The best combined Noise-Air quality and combined exposure to Noise-Air pollution at the microenvironment of the city in after-noon and in summer might be attributed to lower air and noise pollution level due to lower traffic volume in after-noon and higher wind ventilation potential in after-noon and summer (Chowdhury *et al.*, 2015c; Chowdhury *et al.*, 2015d). However, the variable road geometry might have localized effect on the concentration of the air pollutants and traffic noise level. Distinct seasonal variation of combined Noise-Air quality of the microenvironment of the city might be attributed to distinct seasonal variation air quality in the context of Kolkata city; otherwise traffic noise level of the microenvironment of the city had no distinct seasonal variation (Chowdhury *et al.*, 2015d).

Summary of the Principal Component Analysis. The Principal Component Analysis was completed in two iterations. In the second iteration the variable 'Road Width (RW)' and 'Relative Humidity (RH)' was removed from the analysis due to lower (less than 0.50) individual Kaiser-Meyer-Olkin Measure of sampling adequacy in the first iteration. In the second iteration the minimum and the maximum of individual Kaiser-Meyer-Olkin measure of sampling adequacy of the variables were 0.56 (vehicles/4-h) and 0.79 (concentration of $PM_{2.5}$). The Kaiser-Meyer-Olkin measure of sampling adequacy for the set of variables was 0.76 and the Bartlett's test of sphericity was also statistically significant at $P < 0.001$ level. There were two components extracted in the second iteration which had the Eigen-values > 1 (Fig. 2). The cumulative percentage of variance explained by the two extracted components was 72.18%. The minimum and the maximum extracted communalities of the set of variables was of 0.53 (wind speed) and 0.89 (concentration of NO_2).

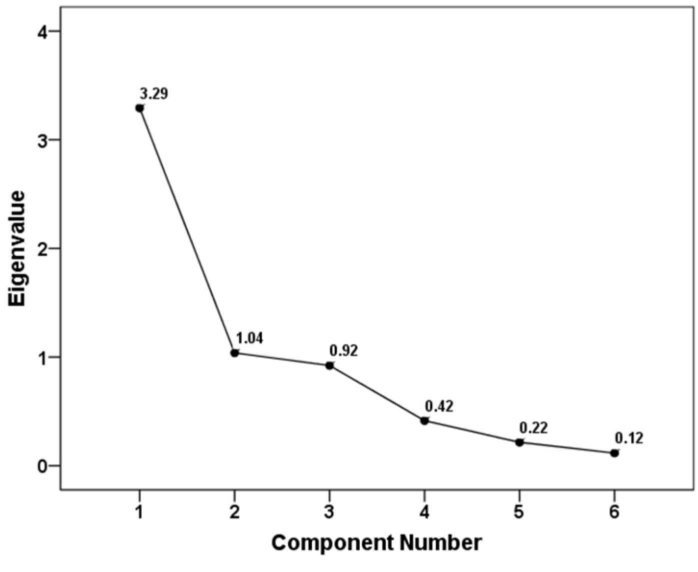

Fig. 2. Scree plot of the extracted components

Significance of the extracted components. The first component explained 50.67% of the variance in the dataset. The component had very strong positive loading with the variables; traffic noise level (0.87), concentration of $PM_{2.5}$ (0.89) and NO_2 (0.94) (Fig. 3). The second component explained 21.51% of the variance in the dataset. The component had strong negative (-0.79) loading with traffic volume. The loading of traffic noise level, concentration of $PM_{2.5}$ and NO_2 under the same component confirms their origin from same source i.e., motorized traffic at the curbside open air microenvironment of the city but they had no linear relationship with the traffic volume; otherwise occurrence of the variable would be under the first component.

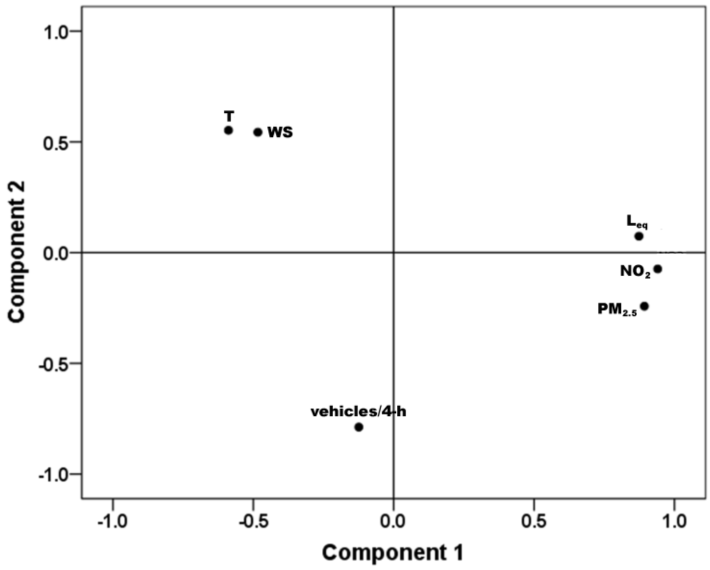

Fig. 3. Rotated component plot

The decoupling of traffic volume and concentration of air pollutants might be attributed to influences of air temperature and wind speed. An increase in air temperature results an increase in the average mixing height thereby, increasing the volume of air circulation and reducing the concentration of pollutants (Spiroska *et al.*, 2011). Air pollutants disperse in the atmosphere by diffusion and drift which also is a direct linear function of intensity of wind speed. The argument is supported by the moderate negative loadings of air temperature (-0.59) and wind speed (-0.48) with the first component. Negative correlation between traffic noise level and air temperature might be attributed to higher pavement temperature which is a direct linear function of air temperature (Danish Road Institute). A reduction in noise level to close proximity of road due to higher pavement temperature was accounted in the research work of Anfosso-LédéE *et al.* (2007) and Bueno *et al.* (2011). Negative correlation between traffic noise level and wind speed might be attributed to atmospheric turbulence. Higher atmospheric turbulence may scatter sound unpredictably close to the road and this also may result a reduction in the close proximity sound levels (NZ Transport Agency research). However, unlike the concentration of the air pollutants traffic noise has lower dependency on the air temperature and wind speed (Allen *et al.*, 2009; Weber, 2009; Can *et al.*, 2011). The inverse relationship between traffic volume and air temperature, traffic volume and wind speed might be attributed to co-occurrence of lower traffic volume of in the sessions of higher temperature and wind speed (non-peak traffic hour or after-noon traffic hour, Chowdhury *et al.*, 2015c).

Factor(s) influencing the degree of correlation. It is clear from the above discussion that intensity of wind speed and atmospheric turbulence generated wind are responsible for determination of the degree of correlation between concentration of the air pollutant(s) and traffic noise level at the curbside open-air microenvironment of Kolkata city. The findings are in line with the findings of Weber *et al.* (2008) and

Weber (2009) (in the context of Essen); Can *et al.* (2011; in the context of Antwerp) and Ross *et al.* (2011; in the context of New York).

Effect of variation of wind speed on the correlation. The collective data set was classified according to the Beaufort scale to determine the effect of wind speed variation more precisely on the degree of correlation between concentration of the air pollutant(s) and traffic noise level at the curbside open-air microenvironment of the city (Table 5). The Pearson's correlation coefficients were calculated between concentration of the air pollutant(s) and traffic noise level for each of the classes to examine its variation with the increasing wind speed. A plot of Beaufort number vs. Pearson's correlation coefficient between concentration of NO_2 and traffic noise level revealed consistently lower correlations between them with increment of the Beaufort number (Fig. 4). This implied higher wind speed consistently lowers the correlation between concentration of NO_2 and traffic noise level at the curbside open-air micro environment of the city. On the contrary the correlations between concentration of $PM_{2.5}$ and traffic noise level at the microenvironment of the city increased initially with the increment of the wind speed and then decreased finally.

Table 5. Classification of the data according to the Beaufort number

Beaufort number	Wind speed (km/h)	Description	Sample size(n)*	Percentage (%) of sample
0	< 1	Calm	0	0.00
1	**1.1 – 5.5**	**Light air**	**24**	**9.45**
2	**5.6 – 11.0**	**Light breeze**	**133**	**52.36**
3	**12.0 – 19.0**	**Gentle breeze**	**83**	**32.68**
4	**20.0 – 28.0**	**Moderate breeze**	**14**	**5.51**
5	29.0 – 38.0	Fresh breeze	0	0.00
6	39.0 – 49.0	Strong breeze	0	0.00
7	50.0 – 61.0	High wind/Moderate gale/Near gale	0	0.00
8	62.0 – 74.0	Gale/Fresh gale	0	0.00
9	75.0 – 88.0	Strong gale	0	0.00
10	89.0 – 102.0	Storm/Whole gale	0	0.00
11	103.0 – 117.0	Violent storm	0	0.00
12	≥ 118.0	Hurricane force	0	0.00

*Total sample size (N) = 254

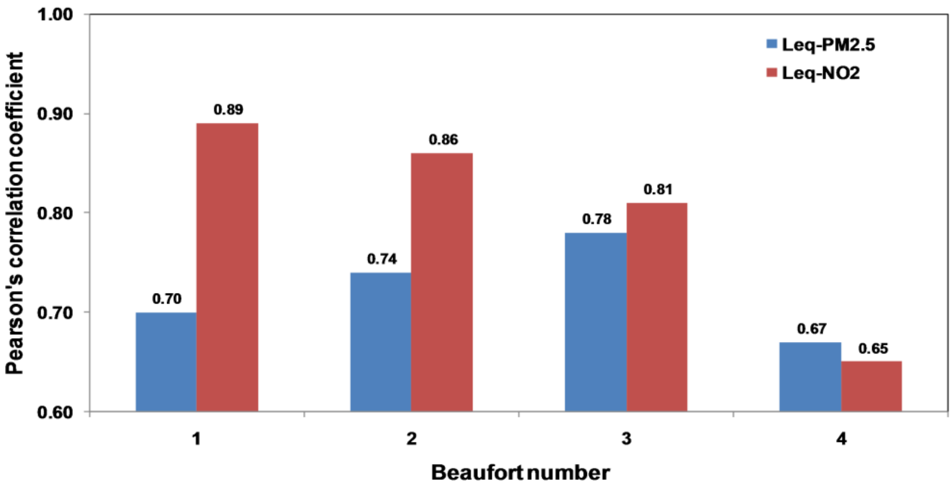

Fig. 4. Effect of wind speed variation on the correlation between concentration of the air pollutant(s) and traffic noise level (the correlation coefficients are significant at P<0.01 level)

CONCLUSION

The following conclusions can be made from the research work:

- Occurrence of moderate positive Pearson's correlation coefficient ($r \geq 0.40$) between concentration of the air pollutant(s) and traffic noise level indicated chances of correlated exposure to these environmental stressors at the curbside open-air microenvironment of the city.
- A higher chance of correlated exposure was confirmed to concentration of NO_2 and traffic noise level than concentration of $PM_{2.5}$ and traffic noise level.
- Average combined Noise-Air quality of the microenvironment of the city was very poor to fair.
- Average quality of the combined exposure to Noise-Air pollution in the microenvironment of the city was poor to excellent.
- The best combined Noise-Air quality and the best level of combined exposure to Noise-Air pollution at the microenvironment of the city was prominently evidenced in after-noon, in summer and under variable road geometry.
- The worst combined Noise-Air quality and the worst level of combined exposure to Noise-Air pollution at the microenvironment of the city was prominently evidenced in evening, in winter and under constant road geometry.
- Intensity of wind speed and atmospheric turbulence generated wind are responsible for determination of the degree of correlation between concentration of the air pollutant(s) and traffic noise level at the curbside open-air microenvironment of the city.

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