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Original Research Article

Network design and evaluation through PM10 & PM2.5 mass loading

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A B S T R A C T

Air Quality has been a complex issue in most of the urban areas due to a variety of source contribution thorough fugitive and line emissions. The ambient air quality data generated has been questionable due to lack of interagency coordination in monitoring protocols and site selections. Above all lack of QA/QC in the overall data gathering and interpretations adds to the problem. The study area of Pune has been into limelight because of its high pollution levels in ambient air and also it being the 13th most polluted city in India thereby selected as demonstration city for the Urban Air Quality Management project taken up by the USEAP, MoEF and GoI agreement since 2002. The present paper deals with an attempt to design a sampling network for ambient air quality measurements and its evaluation through PM10 and PM2.5 mass loadings at selected locations considering the standard siting criteria and overall meteorology. A pilot scale mass loading measurements for a week was carried out during the pre-monsoon period (April 2005) at criteria locations such as residential, commercial, industrial, and sensitive and background areas across Pune city. The results show that the concentration of PM10 varies between 55 to 169 $\mu g/m^3$ whereas PM2.5 mass varied between 40 to 132 $\mu g/m^3$ across Pune. The study is preliminary approach to identify and evaluate sampling network and is suppose to function as a guideline for the future considerations.

Introduction

The pace with which urban air pollution has grown in cities like Delhi, Mumbai and Kolkatta, across the subcontinent in the last decade is alarming (Agarwal, 1999). WHO ranked Delhi as a fourth most polluted mega city of the world (WHO-UNEP, 1992). In Indian subcontinent, it is not just Delhi but some small and medium towns, which are finding themselves in the grip of deterioration of Air Quality (CPCB, 1995). Even though Dehradun located in the Himalayan foothills in Western UP, which now often tops the list of the most polluted places in urban India (CPCB, 1995).

The major source contribution to the air

quality is from fugitive and line emissions. Vehicular pollution contributes 50%-60% in urban air pollution (World Bank, 1994). About 12 million vehicles were registered in Pune during 2004-05 (RTO, 2005). The average vehicle per house is approx 3.33. There is lack of consistency in generated data of ambient air quality not only because improper site selection but also lack of coordination in monitoring protocols and neglected QA/QC. According to the study conducted by CPCB, Pune has been rated as the 13th most polluted city amongst 56 cities of India (ToI, 2005). Total vehicular pollution (PM10) in Pune is 255 Tones/Year i.e. 0.70 Tones/Day (ESR Pune, 2005). The air quality trend in 2004 – 05 is represented in Figure 1.

As per the data represented above, annual average concentration for industrial, Residential and Commercial locations were found to be 88.58 $\mu g/m^3$, 170.08 $\mu g/m^3$ and 195.58 $\mu g/m^3$ respectively. However, PM2.5 monitoring has not been taken into consideration in any of the earlier studies. Besides, since 1991 the land use pattern of the city has drastically changed so there seems to be an urgent need to relocate the monitors and design an effective and updated air quality-monitoring network.

Several methods have been cited for quantitatively establishing the network however; these methods do not provide guidance needed for siting a monitor with the limited database on meteorology and air quality trends. Hougland and co workers presented one of the first analytical techniques for network design. Husain and Khan developed a methodology using Fisher's information measure to determine the optimum number and location of monitors in the network (Husain and Khan, 1983). Noll and Mitsutome (1983) developed a method that establishes monitor locations based on expected ambient pollutant dosage. A more complex methodology developed by Nakamori and Sawaragi (1984) determines the representative areas of monitor stations in urban areas.

The network for air monitoring is usually designed for determination of representative concentrations in areas of high population density, which provides impact on ambient air pollution levels of noteworthy sources or source categories. For siting a monitor, there is requirement to locate monitors either at point of maximum PM concentration (for PM10) or at a location where a population oriented concentration can be measured (for PM2.5). Therefore to locate the monitor, characterization of PM concentration dissimilarity within monitoring area is necessary (Baldauf, et. al., 2002). Some other techniques where the located monitor sites based on maximizing coverage factors, such as strength of emission source, distance from source and local metrology for each source in the study (Houghland, 1976-77).

Considering the above-mentioned facts, there seemed to be an urgent need to have a systematic network design for ambient air monitoring including monitoring in background and sensitive areas. In addition, PM2.5 concentrations seemed to provide deeper insight of the evaluation of the newly selected sites in terms of representative contribution of the sources.

Materials and Methods

Study Area

Study area, Pune (18^0 31' N, 73^0 51' E, 560m asl) is situated on Deccan Plateau. It lays on the leeward side of the Sahyadri i.e. the Western Ghats and is hardly 50Km from the crest of the ghat country. It is 100km east from the Konkan i.e. the west Coast.

The height above the sea level and the leeward location relating to Western Ghats have made city climate moderate and salubrious. The mean daily temperature maximum and mean minimum for the hottest month i.e. May, is observed as 37°C and 23°C, respectively. Relative humidity averages 37% in March and 81% in August. Three fourth of the annual rainfall of 70cm, occur in just four months from June to September. The gross density of population in Pune city is 13,203 persons per sq Km (Census, 2001).

Meteorology

Wind speed and wind direction plotted as Wind rose during the whole year. These represent the annual pattern of wind flow. The wind flow all through the summer season was towards West and Northwest. But all through the winter seasons observed towards East. The Monsoon was observed towards West and Northwest. As the study period was pre-monsoon, the wind direction was towards West to Northwest. The temperature averages 37°C.

Network Design Methodology

The siting criteria used in the present study includes parameters such as vertical placement of sampler, distance from the tree, nearby obstacle distance, distance from nearby road and the road is paved or not (US-EPA, Training Manual 1997). The network designing methodology is based on two basic methods, Statistical and Modeling (Munn, 1991).

However, in the present study above and beyond the statistical method, sites were selected on the basis of siting criteria discussed above. The concept of network designing for air quality monitoring was newly introduced in Pune city (study area).

Instrumentation

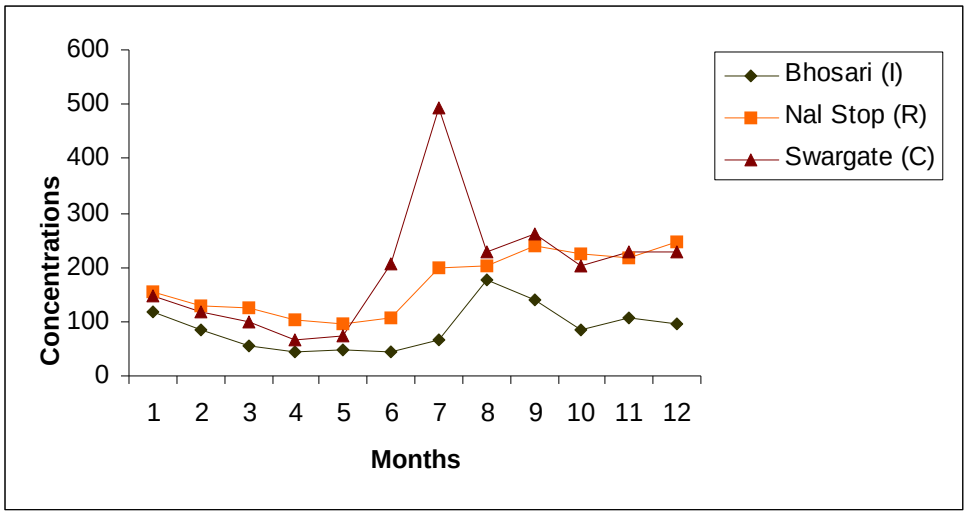
The study of PM10 and PM2.5 was conceded with the help of Airmetrics Low Volume Sampler (MiniVol). The flow rate was adjusted at 5lpm. The sampler was programmed for 24hr operation with special programmable feature. Filter paper was selected considering cost and efficiency thereby using 47mm Pure Quartz which has mat of fibers, better particle collection efficiency, moderate flow resistance and low hygroscopicity (Guidance for Network Design and Optimum Site Selection Exposure for PM2.5 and PM10). Gravimetric analysis as well as filter paper handling was carried out in an Environmentally Controlled Room maintaining 20°C temperature and 40% humidity. Sartorius microbalance with minimum detection level of 1μg was used for weighing. The conventional lab procedure of weighing of paper with folding has been rose above. In point of fact, this practice breaks the filter fibers.

Results and Discussion

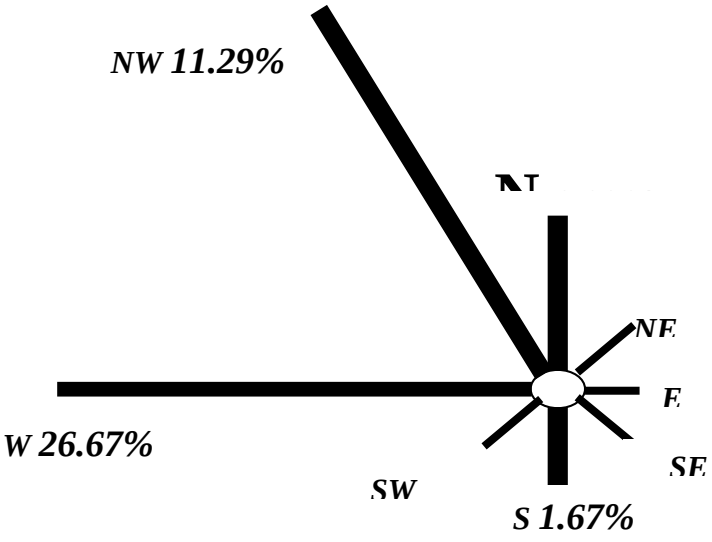
An outline of the comparison of previous and newly located monitors with regards to the parameters considered for network design is represented in Table 1.

The Comparative account given in Table 1 reveals that Swargate site considered as commercial is influenced by high traffic zone, which do not qualify the standard criteria. Also, previous studies PM10 concentrations are apparently higher at Swargate site, which is relevant of the source contributions. Mandai, typical Commercial site selected and convinces guidelines. It is also found that being commercial one it do not has any heavy traffic.

Figure.1 Ambient Air Quality monitored under NAAQM Project



Wind Rose



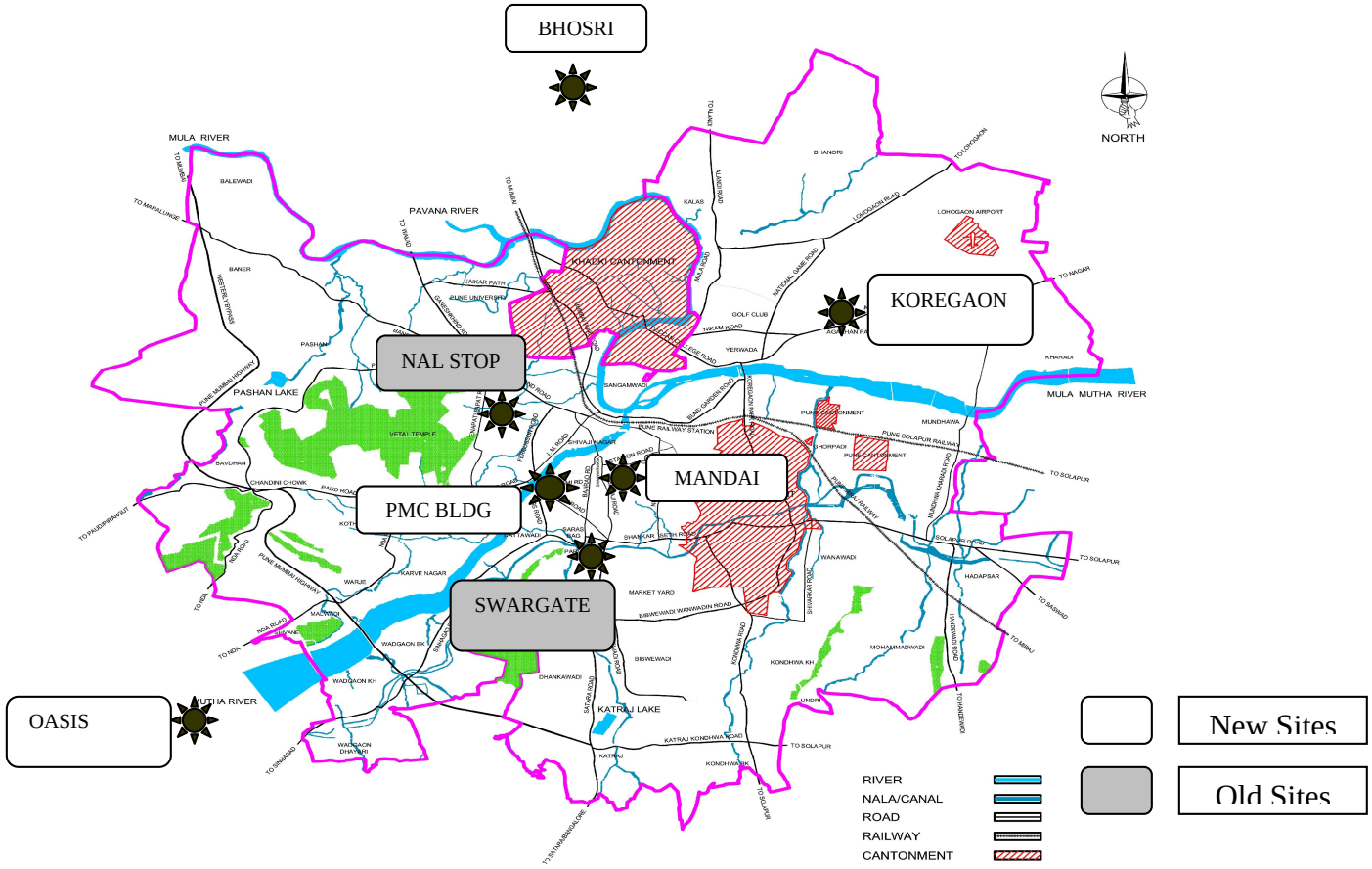

BHOSRI
KOREGAON
NAL STOP
MANDAI
PMC BLDG
SWARGATE
OASIS
NORTH
MULA RIVER
PAVANA RIVER
MULA MUTHA RIVER
KHADKI CANTONMENT
PASHAN LAKE
KATRAJ LAKE
New Sites
Old Sites
RIVER
NALA/CANAL
ROAD
RAILWAY
CANTONMENT

Table.1 Comparison with regards to U. S. Siting Criteria

Criteria	U. S. Siting Requirement	Previous locations			**New locations**				
		Swargate	Nal stop	Bhosari	PMC Building	Mandai	Koregaon Park	Bhosari	Oasis Hotel
Vertical placement	2 – 15 M	4 M	7 M	7 M	15 M	6 M	5 M	7 M	8 M
Spacing from the tree	>= 10 M	3 M	> 10 M	None	9 M	10 M	3-4 M	None	3 M
Obstacle Distance	2x Height difference	Not 2x away	Ok	O.K.	> 2x; O.K.	> 2x; O.K.	Not O.K.	O.K.	>2x; O.K.
Unrestricted Air Flow	>= 270 degrees; no obstruction between monitor and source	Tree and stair wall block	Ok	O. K.	O. K.	O. K.	Presence of Trees and roof top	O. K.	O. K.
Distance to road	>5 M	<5M	>5M	6 M O.K.	> 5 M	3 M	15 M	6 M O.K.	25 M
Paving Category	Paved	Paved Commercial	Paved Residential	Paved Industrial	Paved Residential	Paved Commercial	Paved Sensitive	Paved Industrial	Paved Background

Figure.2 PM10 Concentrations across various locations

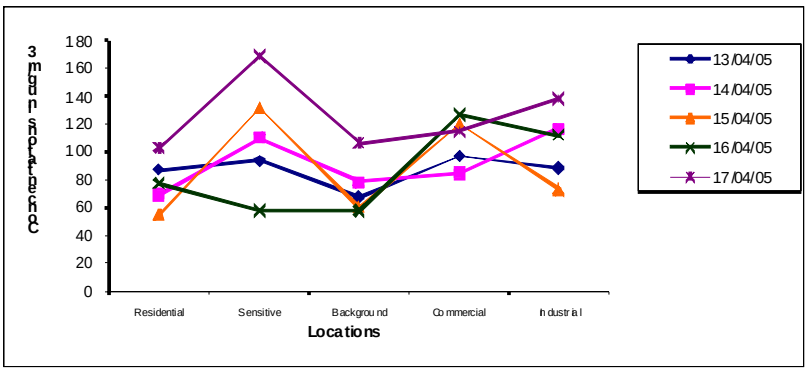
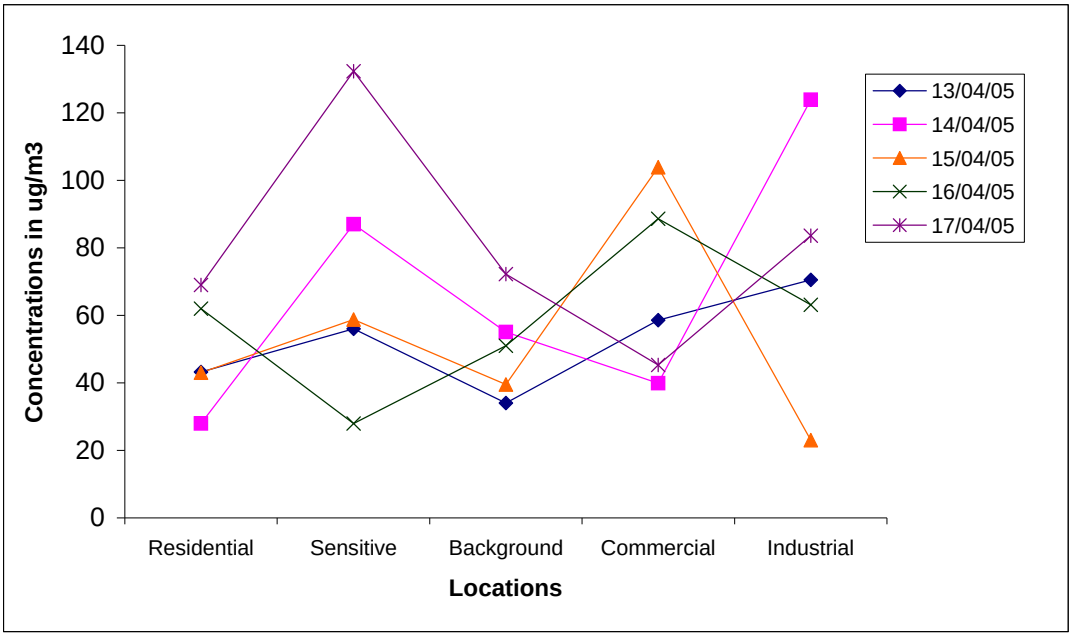


Figure.3 PM2.5 Concentrations across various locations



Some residential area was also found and this can by categorized in Residential one. According to NAAQS the limit is as per residential area.

Previous residential site i.e. Nal Stop, besides being residential, is characterized by high traffic zone. Sampler was placed at the traffic junction thereby resulting in defined source influence. In contrast to the latter, the new location at PMC Building, Navi peth is representative of typical residential area and complies with siting requirement as seen from the Table 1. The industrial location at Bhosari seemed to be ideal for the ambient air monitoring in industrial area and hence selected.

In addition to these, as discussed earlier, background site and sensitive location were also selected considering the same criteria.

The mass loadings of PM10 are presented in Figure 2. The results show that the concentration of PM10 does not vary much across the individual sites except on the last day of sampling in the residential and sensitive areas. PM10 concentrations found were well within the prescribed limits, and even though some of them have crossed the limits marginally. Construction activity was observed near the Sensitive area of Koregaon Park providing evidence for high ambient concentrations. Due to that there might be increase in concentration.

The concentration of PM2.5 are presented in Figure 3 shows considerable variations across individual sites as well as across various sites thereby revealing the characteristic feature of classification of various land use patterns selected for sampling. Standards for PM2.5, has not yet been defined for India. Sensitive area (Koregaon Park) shows higher variations in concentrations through the sampling period as compared to rest of locations which can again be contributed to the construction activities as discussed above.

Residential site i.e. PMC Lab building has provision of sampler placement at 20m height, which was following US siting criteria. PM10 Concentration for residential site varied from 55μg/m^3 to 103μg/m^3. And the industrial location varied from 73μg/m^3 to 138μg/m^3. PM2.5 Concentration for residential site lies between 28μg/m^3 to 69μg/m^3. And the industrial location varied from 23μg/m^3 to 124μg/m^3.

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