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CREATION OF AMBIENT AIR QUALITY INFORMATION IN A RAPIDLY GROWING INDUSTRIAL CENTRE USING REMOTE SENSING & GIS - A NOVEL STUDY

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ABSTRACT

With the increase in population and built up area, the pressure has increased on the civic amenities and is directly affecting the quality of environment. The two main reasons for undertaking the present study are rapid growth in population and urban sprawl, uncontrolled industrialization and unchecked immigration and the likely impact of these land use changes on air quality. The city of Hyderabad is expanding at a tremendous pace and the urban growth is reflected in the traffic intensities on the roads. Adequate information on changing air quality with increasing traffic loads is crucial for effective management of air quality in the future. Keeping this in view, the present study aims for creation of ambient air quality information in rapidly industrially growing urban center of Hyderabad. Ambient concentrations were measured from April 2005–May 2006 at 44 selected sites in and around Municipal Corporation of Hyderabad (MCH). The data consisted of 24 hr average of Sulfur dioxide (SO_x), oxides of nitrogen (NO_x), suspended particulate matter (SPM) and respirable suspended particulate matter (RSPM). The measurements were made in an effort to characterize the air pollution in the urban environment of Hyderabad and assist in the development of linkage between land use practices and air pollution levels. The spatial variability of air pollutants and the predominant land use thematic layers was assessesed in GIS and Remote Sensing environment. The spatial variability of air pollution and significance of land use practices on the prevailing quality were assessed using statistical correlation and Boolean overlay techniques.

INTRODUCTION

Urban growth is inevitable and the systems are becoming ever larger and increasingly complex as urban economies, social and political structures and norms, and transportation and other infrastructure systems and technologies evolve (Sadik, 1999). Urban air quality is a major concern throughout the world (Karen Bickerstaff, 2001). The pace of urban development, together with the type of social and economic forces that drive it, can have profound implications for the population in and outside of urban areas (Fenger, 1999 and Baldasano, 2003).

While urbanization can bring improvement to people's income and lifestyles, it also comes with negative environmental and social impacts. These

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negative impacts threaten our quality of life at every level, from the health of the individual citizen, to the stability of the global economy, to the long-term survival of humans and natural systems around the world (Devas & Radkodi, 1993). Some of the major environmental issues associated with urbanization and the corresponding increases in population density are those related to water quality, waste management, and air quality (Scholorling, 2000).

The Hyderabad urban system depends primarily for its operation upon the consumption of fossil fuels. Hyderabad city is under significant influence of anthropogenic emissions, the levels of concentration of components were very similar to those at other Indian sites (Kulshrestha *et al.* 2003). The city's systems which have also evolved particular land use and transportation patterns, which are far from optimal in their economic efficiency, social equity and environmental performance. As well as benefits, the continuing growth of city also brings disbenefits including congestion and pollution (Reddy and Chari, 2001). Pollution brings damage to health, degradation of the built and natural environment and loss of amenity.

The desirable path for future city development in any country is one which seeks to provide sustainable city in terms of minimizing the resource inputs, such as energy, and reduce waste outputs, such as air pollution and greenhouse gases, while optimizing land use, transport systems and infrastructure (Paul Ekins, 2001). The prime objective of the assessment study is to determine the need for and to propose actions that will maintain or improve air quality in Hyderabad for our ongoing project on Impact assessment of land use and air quality.

DESCRIPTION OF THE STUDY AREA

Hyderabad city, the capital of the state of Andhra Pradesh is located at the heart of the Deccan plateau of the Indian sub-continent. The total study area of Municipal Corporation of Hyderabad (MCH) is 179 Km^2 and divided into 11 planning zones. The study area is situated between 17^0 18′ 26″ and 17^0 27′ 40″ North latitudes and 78^0 22′ 26″ and 78^0 33′ 26″ East longitudes and is at an altitude of 536 m above Mean Sea Level (MSL). The climate is fairly equitable with a daily mean maximum temperature varying from a minimum of 11.6^0 C during the month of December to a maximum of 40.56^0 C in April. Hyderabad gets its rainfall mainly from southwest monsoon with the total annual average rainfall of about 73.55 cm. It is located at an altitude of 570m above mean sea level.

METHODOLOGY

Developments in computer hardware and software have made possible electronic mapping with dynamic connections between maps and database information. These developments make it possible to manipulate maps and information to analyze spatial aspects of data (Ranger *et al*. 2002). In evaluation of impacts of land use/land cover changes on air quality, broadly two types of data products are generated, spatial data and non- spatial attribute data. The spatial data is comprised of land use/land cover, point sources. The non-spatial or attribute data is composed of air quality parameters, and air quality index.

Description of sampling sites

The 44 sites were chosen to be representative for the typical Landuse category in the study area. They differed mainly with respect to the road traffic density and predominant landuse and population densities. Five sites were typical industrial locations, whereas fifteen were residential sites with low, medium and heavy traffic density and the remaining sites were allocated to be commercial and heavy traffic zones.

Analytical procedures

The air pollution measurements were carried out for 1 yr, starting from April 2005 to May 2006, with a frequency of one week at one location sampling. Each sample represents a continuous TSPM, RSPM, NO_x and SO_2 collection of 24 h duration. Rains in India are limited to four months of monsoon period with intense and continuous rainfalls. Hence, during this season, the samples were collected only during dry spell days. SPM were collected on glass fiber filter paper (size 20.3 - 25.4 cm), using a Respirable Dust sampler, operated at a flow rate of $1.0m^3$/ min. NO_x and SO_2 were collected by aspirating ambient air through absorbent solutions; sodium tetrachloromercurate for SO_2 and a mixture of sodium hydroxide and sodium arsenate for NO_x, with an aspiration rate of 1. $0m^3$/ min Sample processing and analysis SO_2 and NO_x were analyzed colorimetrically using the method of West and Gaeke and modified method of Jacob and Hochheiser, respectively.

Information of land use/ land cover

The spatial data is derived from satellite sensing system and survey of India toposheets. The satellite sensors are panchromatic and LISS-III sensors of IRS-ID satellite, Survey of India toposheets are 56K/7 and 56K/11 on 1:50,000 scale. In this study, the remote sensing data in the digital mode is used and is obtained by LISS III and PAN of IRS ID. Figure 1 shows the raw satellite imagery for Hyderabad city. LISS III sensor operates in four spectral bands; there are separate optics and detector arrays for each band. Map of 1:50,000 scale obtained from SOI covering the entire study area is used to extract the Ground Control Points (GCPs) and to demarcate the boundary of study area. This information is then used for image registration of LISS III and PAN digitally using EASI/PACE software.

Road segments are uniquely defined by its road code and the nearby road segments. The road network has 373 road codes and 1,907 road segments corresponding to an average of about nearly 5 road segments per road code. In order to display street names, a database with road codes and street names was established based on the address database as suggested by Bachmann et al (Bachmann, 2002). The spreadsheet with road and traffic data included street width, travel speed and traffic load of the various categories such as passenger cars, vans, Lorries and buses.

Air quality index calculation

Vast amount of data that are generated as a result of air quality monitoring programmes complicates the meaningful interpretation (of data) and demands extensive statistical and computational efforts. In this research, adaptability of some of the existing AQls that have been used by various agencies is examined. There are several types of AQls cited in the literature having different criteria and mathematical functions, at times, leading to confusion. There is no single universal AQI (Anjaneyulu *et al.* 2001). The Pollution Standards Index (USEPA, 1998) (PSI) that is based on additive function of sub indices was examined for city of Hyderabad.

The air quality index is calculated using the following equation. The mathematical functions for calculating sub indices are proposed after considering health criteria and sub index values from the literature particularly from the website of USEPA (USEPA, 1976; Sharma *et.al* (2001)). The pollutants included in the index are:

$S0_2$, SPM, 0_3, $N0_2$, PM_{10}, CO and SO_2 SPM.

The quality of air in the study area can be estimated from the air quality index. The air quality index was calculated from the observed TSPM, RSPM, NOx and SO2 values using the formula;

$$AQI = ¼ * I_{SPM} / S_{SPM} + I_{RSPM} / S_{RSPM} + I_{SO2} / S_{SO2} + I_{NOX} / S_{NOX} * 100$$

Where,

I_{SPM}, I_{RSPM}, I_{SO2} and I_{NOX} = Individual values of suspended particulate matter, respirable particulate matter, sulfur dioxide and oxides of nitrogen respectively.

S_{SPM}, S_{RSPM}, S_{SO2} and S_{NOX} = Standards of ambient air quality.

The air quality index was individually calculated for all the sampling stations, and the quality of air was estimated. The index is classified in five categories i.e. 0-25 Clean air; 26 - 50 Light air pollution; 51-75 as moderate air pollution; 76- 100 as heavy air pollution and greater than 100 as severely polluted. Statistical analysis of the data was performed with the statistical software Origin 6.

Pollution interpolation studies

Arc/Info GIS spatial analyst module was used for interpolation in three dimensions. Inverse distance interpolation is used for modeling between the monitoring stations. Arc View is a computer software package that stores information about points, lines, and polygons, as well as the spatial relations between these features (Ian Masser, 2001).

This method of interpolation combines the idea of Thiessen polygon with the gradual change of trend surface. It considers weighted moving average. Weights are computed from a linear function of distance between sites of points and the points to be predicted. In this method the size of the starting radius is specified, which defines the starting search area for interpolation points around the grid point. The general theory underlying inverse distance weighing interpolation is that points closer to the estimation location are more influential than points farther away (Watson, 1992).

Identifying the impact of land use/ land cover on air quality

GIS software such as ArcView can associate databases of attribute information (pollution information, point source data etc) with associated spatial objects. One database might contain information about streets names and ambient air quality information; another might have Landuse category, pollution sources information. Data can be displayed as thematic maps. For example, population information in a census database can be displayed as a dot-density map or by shading the census tracts according to their population. In addition to feature/object attribution (air quality index), the notion of topology is critical in GIS- each feature (point/line/polygon (location type) in GIS can "answer" three additional questions- "What is the air quality index," "what the land use/ land cover status," and "which type of point sources are surrounding the region?"

RESULT AND DISCUSSION

Land use/ land cover of Hyderabad

Two striking factors of Hyderabad's urban growth are low density scattered development of urban fringe and absence of any identifiable visual character. The growth of the city of Hyderabad got an impetus from industrialization after 1961. There was a speculative growth pattern from 1964 to 1974. The area occupied by built up land in 1964 was 17092 hectares. During the late 70's and 80's the extension of urban sprawl of Hyderabad has been inhibited. The hitherto unoccupied areas of places were occupied. The boulders and tars, which were lying protected, were broken to be used for foundation stones of buildings coming up on the same sites. The sprawl area of Hyderabad between 1975 and 1991 is estimated to 19238 hectares, which accounts for 8.67% of the total geographical area. Figure 2 shows the land use/ land cover classification map for the Hyderabad city.

Air pollution characteristics

City average pollution characteristics for all the pollutants reveal that the excepting sulfur dioxide all pollutants frequently exceed the NAAQS standards for 24 hr average and are below 8hr average values. Table 1 presents statistical data on the concentrations of the measured air pollutant concentrations at 44 selected locations in Hyderabad during the sampling period. Arithmetic averages for different places and comparison of the concentration levels among the sites are given in terms of arithmetic and geometric mean, median and range of the values. Figure 3 to

Table 1. Air pollutant concentrations at selected locations in Hyderabad

Parameter	Mean	Sd	Sd (e)	Range
Frequency count for whole of the study area				
TSPM	327.54545	88.68985	13.23984	379
RSPM	158.09091	46.09515	6.89735	217
SOX	67.84091	24.83301	3.45321	98
NOX	4.82727	1.93555	0.29846	9
AQI	95.52273	26.90725	3.90766	135
Frequency count for residential areas				
TSPM	285.64286	59.68139	16.94758	198
RSPM	136.35714	30.50601	8.1628	94
SOX	48.78571	14.20823	3.79831	53
NOX	3.58243	0.94771	0.26059	4
AQI	86.24429	13.7267	3.67347	49
Frequency count for industrial areas				
TSPM	358	79.95885	36.31147	174
RSPM	174.3	43.1086	17.98711	83
SOX	94.8	37.48492	14.09048	87
NOX	7	1.74205	0.7847	5
AQI	65.8	17.58271	7.86877	42
Frequency count for Traffic/Commercial areas				
TSPM	345.36	97.67294	19.33559	366
RSPM	168.8	49.25488	9.857	218
SOX	74.56	17.90857	3.38885	63
NOX	4.97	1.95789	0.39724	9
AQI	106.17	27.56506	5.37981	115

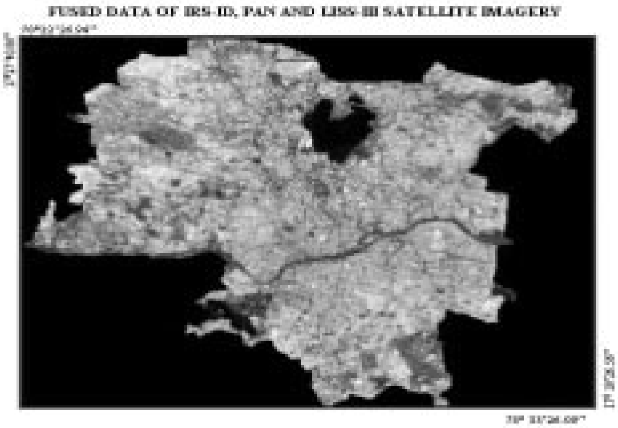


Fig. 1 Fused satellite data of IRS -ID and LISS - III satellite imagery

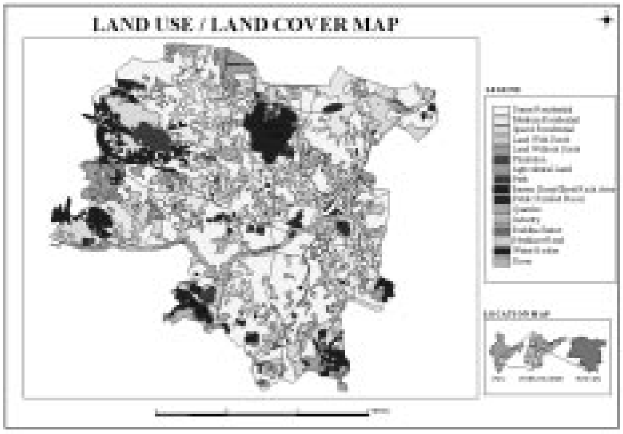
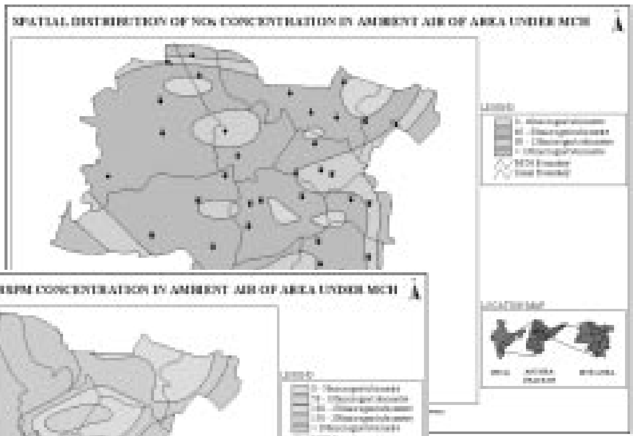
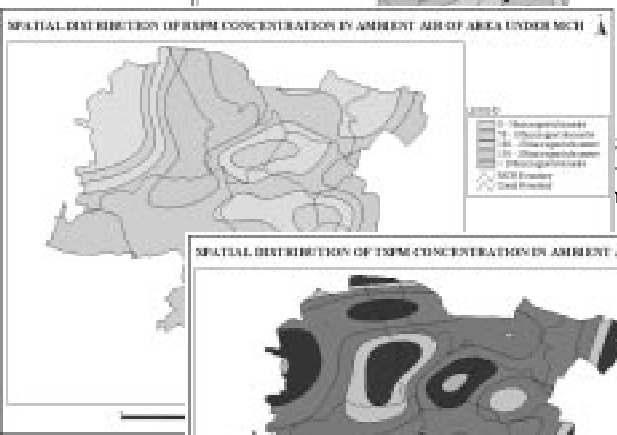


Fig. 2 Land use /land cover map of the study area





itrogen

Figure 4 Spa

Fig. 4 Spatial distribution of respirable suspended particulate matter

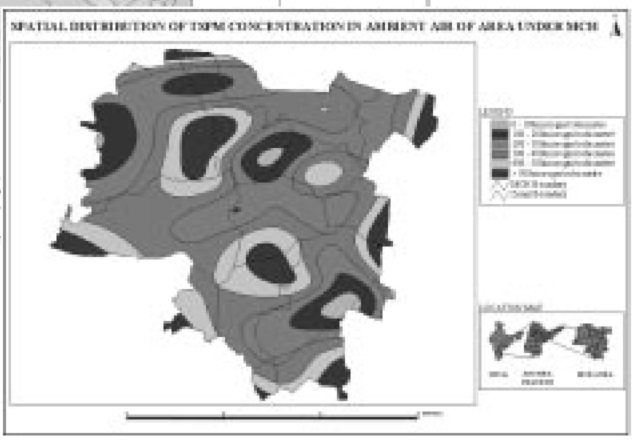


Fig. 5 Spatial distribution of total suspended particulate matter

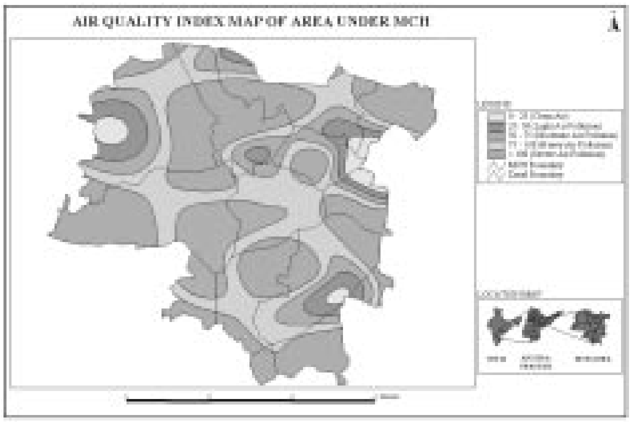


Fig. 6 Spatial distribution of air quality index

Figure 7 shows the interpolated air pollution maps for Hyderabad city during the study period.

Spatial variation

The ambient concentrations of air pollutants at a specific location are largely dependent on the point source emissions, predominant land use practices and transport atmospheric scavenging processes. Figure 8 to Figure 12 shows the statistical character-

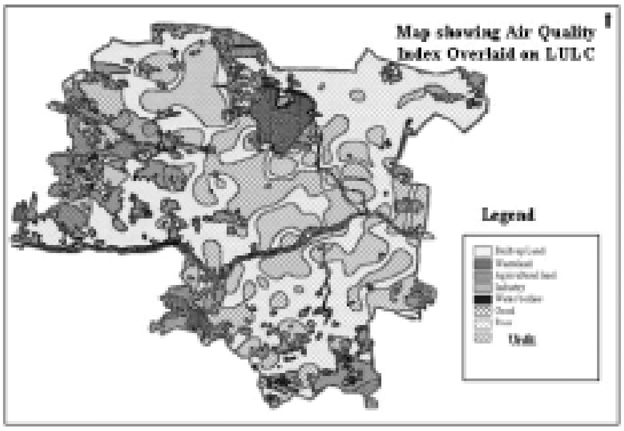


Fig. 7 Impact of LULC on air quality in Hyderabad

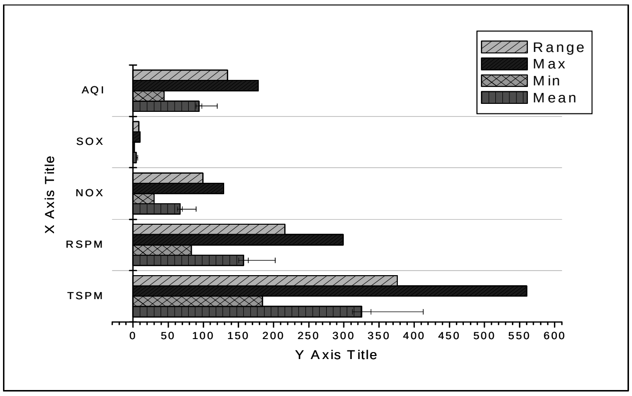


Fig. 8 Spatial statistics of air pollution at Hyderabad

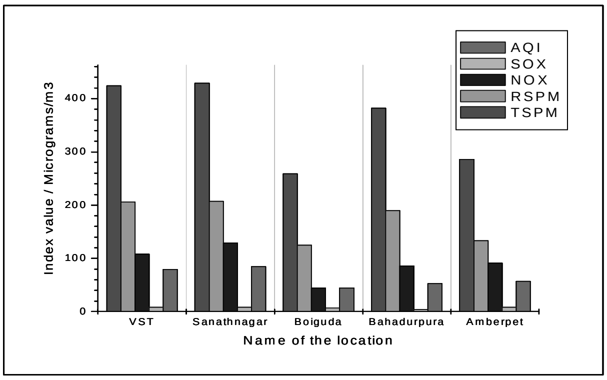


Fig. 9 Spatial variation of air quality parameters at industrial location

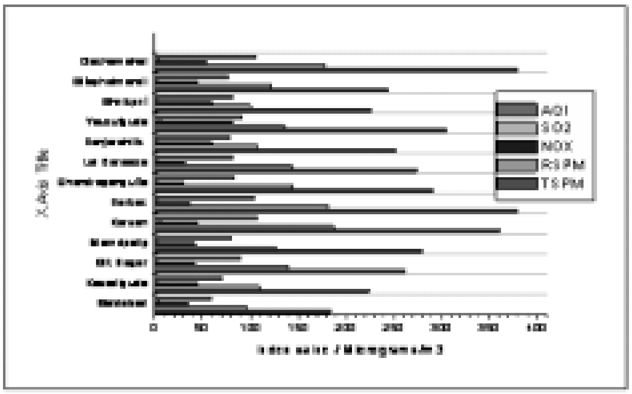


Fig. 10 Spatial variability of air quality parameters at residential locations

Fig. 11 Spatial variability of air quality parameters at residential locations

Fig. 12 Spatial variability of air quality parameters at heavy traffic locations

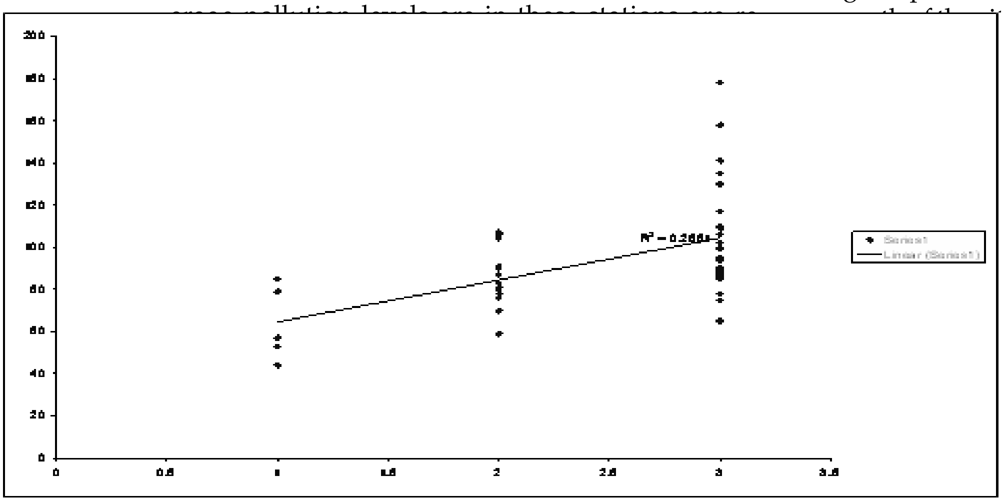
istics for different land use categorized samples in Hyderabad. The statistical evaluations carried out for samples of different land use origin suggested that higher concentrations are likely to be found at busy streets and at commercial locations in Hyderabad.

The total number of sampling stations from residential back ground is 14. The average pollution levels are 184, 96, 30 and 3μg/m^3 for TSPM, RSPM, Oxides of nitrogen and sulfur dioxide respectively. The recorded values were observed to exceed the National Ambient Air Quality Standards (NAAQS) for 13 sites

Fig. 13 Correlation coefficient between land use and air pollution

for TSPM 12 sites for RSPM and 12 for oxides of nitrogen whereas the oxides of sulfur are found to be within the limits at all places.

Out of the 44 sampling stations 5 locations were observed to be with industrial background. The av-



land use on air quality was assessed by carrying out the correlation studies, the results indicate the significant relation between type of the land use and number of vehicles plying and the corresponding land use. Figure 13 shows the correlation between land use and air quality in Hyderabad. The correlation studies carried out indicate the impact of land use on air quality is significant with places of commercial and industrial locations the pollution levels are high.

CONCLUSION

The study carried out on impact of land use on air quality has suggested that the Hyderabad city is facing air pollution problems because of unplanned
and city roads. Hyderabad city can
esentative of air pollution and envi-
ems that affect most cities in devel-
Given the present favorable eco-
s further increase in air pollution
vehicular mobility, industries, and
n be expected in the next few years.
l issues are not considered in land-
d zoning and in the further urban
, it would not be possible to improve
al situation and its negative effects
d health of the ecosystems.

akumar, I, Madhav T., .H. Rao, T. 2001. Online air pollution monitoring - Strategies for monitoring air pollution in Hyderabad, *Proceedings of Intl Conference on Industrial Pollution and Control Technologies*. 324- 328.

Ian Masser, 2001. Managing our urban future: The role of remote sensing and geographic information systems. *Habitat International.* 25 : 503–512.

J.M. Baldasano, Valera, E. and Jimenez, P. 2003. Air quality data from large cities, *The Science of the Total Environment.* 307 : 141–165.

Jes Fenger, 1999. Urban air quality, *Atmospheric Environment.* 33 : 4877-4900.

Karen Bickerstaff, 2001. Public understandings of air pollution: The & localization of environmental risk. *Global Environmental Change.* 133-145.

Paul Ekins and Sandrine Simone, 2001. Estimating sustainability gaps: methods and preliminary applications for the UK and the Netherladns. *Ecological Economics.* 37 : 5– 22.

Raghavachari, S. and Ranadhir, P. Reddy, 2001. Transportation planning for Hyderabad: Policy and Practice, Municipal Corporation of Hyderabad, AP, India.

Ralph Ranger, 2002. *American Journal of Evaluation.* 23 (4) : 469– 479.

Sadik, N. 1999. Meeting the urban population challenge. *City Development Strategies.* 1 : 16–23.

Scholorling, Devas, N. and Radkodi, C. Managing fast growing cities, New approaches to urban planning and management in the developing world. Essex: Longman, 2000.

Scholorling M., Urban transport and its compliance with future air quality standards, *Sixth International Conference on Urban Transport and the Environment for the 21st Century*. July 26-28, Cambridge, UK. 2000. (9 p).

Sharma, M., Maheshwari, M., Sengupta, B. and Shukla, B.P. 2003. Design of a website for dissemination of air quality index in India, *Environmental Modeling & Software.* 18 : 405 -411.

Kulshrestha, U.C., Monika, J. Kulshrestha, Sekar, R., Sastry, G.S.R. and Vairaman, M. 2003. Technical note Chemical characteristics of rainwater at an urban site of south-central India. *Atmospheric Environment.* 37 : 3019–3026.

USEPA. 1976. Federal Register. 41:174 - Tuesday September 7.

USEPA. 1998. Federal Register. 63: 236/Wednesday, December 9.

USEPA, 1998, Federal Registrar. 63: 236,Wednesday, December 9.

Watson, D. F. 1992. *Contouring: A Guide To The Analysis and Display of Spatial Data*, Pergamon Press, ISBN 0 08 040286 0, New York, USA.

William, Bachman, Wayne, Sarasua, Shauna, Hallmark, and Randall Guensler, 2000. Modeling regional mobile source emissions in a geographic information system framework. *Transportation Research Part C: Emerging Technologies.* 8 (1-6) : 205-229.