Bull Environ Contam Toxicol (2007) 79:202–208
DOI 10.1007/s00128-007-9163-1

# A Comparative Emission Profile of an Urban Area in Madhya Pradesh, India

**H. K. Gupta · K. Gupta · P. Singh · A. K. Singh · R. C. Sharma**

Received: 11 April 2007 / Accepted: 1 June 2007 / Published online: 17 July 2007


**Abstract** This paper emphasizes on mathematical and field work approach to diagnosing the environmental pollution for Indore, India. These applications are based on the time-series statistics and for three semi-industrial as well as residential areas. The generalized additive models finds as a best fit-model in terms of autocorrelation and reduction of over-dispersion. The interdisciplinary study works on the principal of pollutant source, meteorological parameters, pollutant types, emission rates and various chemical processes. Several chemical or industrial processes like iron and steel production, combustion of fossil fuels, biomass burning, thermal power plants are major polluter in most of the mega cities.

**Keywords** Emission · Sources · Anthropogenic growth · Industrial pollution · Chemical approach

Air pollution in India has been aggravated by the growth in the size of cities, rapid economic development, industrialization and increasing traffics. The movement of people to urban areas and unplanned urban and industrial development leads to the air pollution problems. This has resulted in a number of mega cities in India becoming among the worst polluted cities in the World. Using GIS-Remote sensing techniques are found to be important techniques to measure the urban agricultural growth land loss near and around the Indore city. At the global scale the city lies between 20°20′–23°05′ and 75°25′–76°14′. Presently the city population is around 21 millions, but it has further projected population of the city will increase up-to 27 millions by 2011. Industrialization; topographical location are the prime location play a major role for environmental problems. Municipal officials in Indore are aware of the need for better planning to ensure a sustainable future for the city and its surrounding areas. A number of small to large scale industries exist in and around urban centers. In addition, small scale industries also play an important role in pollution generation activities with their dispersion potential. In addition to anthropogenic sources, climate and natural phenomenal sources also play an important role in the build up of pollution levels. Indore has a semi-arid climate with an extreme seasonal variation like hot summer and light rainfall in monsoon months and little cold in winters. Mean while the monthly temperature ranges from 14.3°C in January to 41°C in June with annual rainfall of 800 mm annually. The annual mean temperature is 25.3°C and the rainy season witnesses least $PM_{10}$, SPM and RSPM pollutants particles due to washout of these pollutants along with rains. Ground-based temperature inversion regulates the rural as well as urban mixing height; atmospheric turbulences; wet and dry deposition; pressure; temperature effects; humidity ratio and pollutant dispersions in the study areas (Polo-Ground, Kothari-Market and Telephone-Nagar). The assessment of air quality calculations has been performed by using the primary and secondary data, which have been taken from the field observation spread around 10–20 km in the city

H. K. Gupta (✉) · A. K. Singh · R. C. Sharma
School of Future Studies and Planning (Faculty of Engineering Sciences), Devi Ahilya University, Khandwa Road, Indore 452 001, India
e-mail: h.g@rediffmail.com

K. Gupta
Department of Chemistry, D.B.S. (P.G.) College, Chhatrapati Shahu Ji Maharaj University, Kanpur 208 007, India

P. Singh
School of Journalism and Mass Communication, Devi Ahilya University, Khandwa Road, Indore 452 001, India

regions. The pollution data related with point (Polo-Ground), line (Kothari-Market) and area (Telephone-Nagar) sources has been used for the emissions inventory calculations for the urban study areas.

According to a European survey, the annual mineral dust load in SPM varies from 13% to 37% in Europe, (Putaud 2004; Van Dingenen 2004). Southern Mediterranean countries experience several transient episodes (2–4 days) of transported Saharan dust each year, leading to levels exceeding 25 μg/m$^3$ and 10–15 μg/m$^3$ in daily (Rodriguez 2004). The majority of SPM emissions to the atmosphere are attributable to natural and anthropogenic sources, such as suspended terrestrial dust, oceans and forest fires and natural gaseous emissions. The local traffic and combustion source category was identified chiefly based on high loadings of $NO_X$, or specific point source near the measurement site. Adachi and Tainosho (2004) have proposed a potential marker for traffic related emissions. Mostly, the suspended particulate matters are major urban air pollutants. The particulate levels in North America and Western Europe rarely exceeding in the ranges from 50 to 400 μg/m$^3$, but the major Indian metro cities like Delhi, Mumbai, Kolkata and Chennai are still not following same paths. The present study deals with methods of chemical sources and its purity of giving estimates, aimed at describing the point, area, and line sources with human exposure to anthropogenic evolutions for selected air pollutants of mega cities in India. More information is available regarding air pollution at Indore in form of stray reports. There has been an extended air pollution monitoring program functioning under National Ambient Air Quality Monitoring (NAAQM) project with three stations Polo-Ground, Kothari-Market and Telephone-Nagar in the city to keep constant vigil on the air quality status since 1990 (CPCB 1995).

## Materials and Methods

In the current study generalized additive models (GAMs) came out as a best fit-models in terms of autocorrelation and reduction of over-dispersion. The GAM can be useful to suggest functional forms for parametric modeling to checking an existing parametric model for bias. Trends and seasonality have been well parameterized in a Poisson autoregressive model, results should not differ substantially from those obtained using GAM. The study has been performed and suggested as simple "Simulation Model" with flexible alternative option for time-series regression analysis for major pollutants like SPM, $SO_2$ and $NO_X$ instead of chemical or experimental setup.

For study purpose the suspended particulate matters were collected in the city of by pass-roads; railway tracks; railway stations and near air ports during the field work. The high volume sampler was used for collecting the SPM, RSPM, $SO_2$ and $NO_X$ pollutants load on What-man papers with an average constant flow rate of 1.5 m$^3$/min. The samples for gaseous pollutants like $SO_2$, $NO_X$ as well as SPM and $PM_{10}$ were collected as per standard procedures (Katz 1977). The average emission factors for all pollutant with respect to years (*i*), processes (*k*) and pollutant types (*j*) was calculated by using meteorological parameters (correction factors) and basic emissions rate for primary and secondary pollutants. The below is the defined simple "Simulation Model" in terms of average emission factor ($EF_{i,j,k}$) was established to observe primary as well as secondary pollutants emission rate through Eq. (1):

$$\mathrm{EF}_{i,j,k} = \sum_{m=1}^{n} \left[ \left( \frac{f_{\mathrm{CR2}} \times \rho_{\mathrm{uni}}}{k_{\mathrm{2uni,eff}}} \times Q_1 \right) \times \left( \mathrm{BER}_{j,k,m} \times \mathrm{CF}_{j,k,m} \ldots \right) \right] \tag{1}$$

where $EF_{i,j,k}$ = Average emissions factor for year *i*, pollutant *j* (RSPM, $PM_{10}$, SPM, $SO_2$, $NO_X$), and process *k*.

$f_{CR2}$ = Function slope of the secondary pollutant [impacts/receptor (g/m$^3$)]
$\rho_{uni}$ = Receptor density (receptors/m$^2$)
$Q_1$ = Emissions rate (velocity) of the primary pollutant (g/s).
$k_{2uni,eff}$ = Effective depletion velocity (m/s).
$BER_{i,j,k}$ = Basic emissions rate for pollutant *j*, process *k*, and model year *m*.
$CF_{j,k,m}$ = Correction factors (temperature, pressure, wind speed, wind direction, humidity) for pollutant *j*, process *k*, model year *m*.

Numerical values of $k_{uni}$ and $k_{2uni,eff}$ by fitting the dispersion result to know effective depletion velocity (m/s), and $k_{uni}$ for different pollutant (Manahan 1994). The samples were collected by using high volume sampler at constant flow rate 1.5 m$^3$ per minute and the main criteria to consider three areas as whole Indore was (1) availability of the primary or secondary data (2) rapid industrial, commercial and residential activities (3) chemical effects or change in climatic and weather events has occurred since last 30 years of span over Indore city. In point of view many studies are being carried out to calculate the ambient air quality status with respect to $PM_{10}$, SPM, RSPM, $SO_2$, $NO_X$ and other related major pollutants or particulate matters.

## Results and Discussion

The present study implies sufficient results in developing Indian cities, which are based on the mathematical approach, where it has to consider that the source and

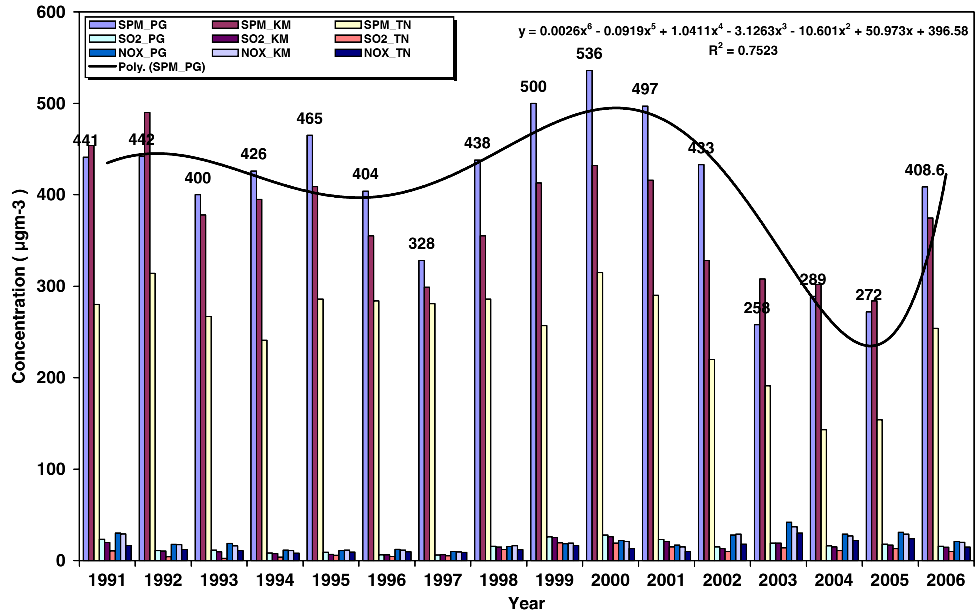



**Fig. 1** Annual air quality emission profile of Polo-Ground, Kothari-Market and Telephone-Nagar for major pollutants (SPM, $SO_2$ and $NO_X$)

pollutant are fairly well mixed vertically in the planetary boundary layer with variation of emission factors ($EF_{i,j,k}$) that is are not too large. Furthermore, averaging site-specific results over a range of emission sites are mathematically equivalent to averaging over population distributions, which brings the effective population distribution closer to uniformity. After the primary and secondary pollution analysis the damage cost estimation with best fit-poly function regression analysis has found to be equal to $R^2 = 0.75$ for SPM, $SO_2$ and $NO_X$ pollutants in terms of concentrations in μg/m$^3$ with decreasing trend, which is represented for Polo-Ground, Kothari-Market and Telephone-Nagar areas (Fig. 1). Similarly the annual autocorrelation factor analysis for SPM, $SO_2$ and $NO_X$ air quality variations for (a) Polo-Ground (PG) (b) Telephone-Nagar (TN) (c) Kothari-Market (KM) since 1991–2006 has been evaluated with lag numbers (Figs. 3, 4, 5). The graphical trends in the result proves that the pollution emission profile degrading air quality not only in Metros like Delhi, Kolkata, Chennai and Mumbai, but also in Indore, Bhopal, Jabalpur, Nagda cities of Madhya Pradesh. The economic; cost analysis; health evaluation; environmental factors and natural phenomenon has substantiated e.g. a house sparrow, which has become increasingly uncommon sight or rare-delight due to increasing profile of anthropogenic toxicants and temperature in an urban areas nowadays, hiding behind the leaves in city gardens (Fig. 2). Consequently the temperature directly and indirectly affects tree's life span with an average reduced age factor of 25%–50% on yearly basis (Table 1). Other than this the formation of aerosol brown cloud (ABC) layer has been observed in April month, 2007 due to intermixing of gaseous and dust particles in the sky. Even the stars in the sky were invisible because of the anthropogenic as well as gaseous loads and dust particles were very high for the formation of ABC layer.

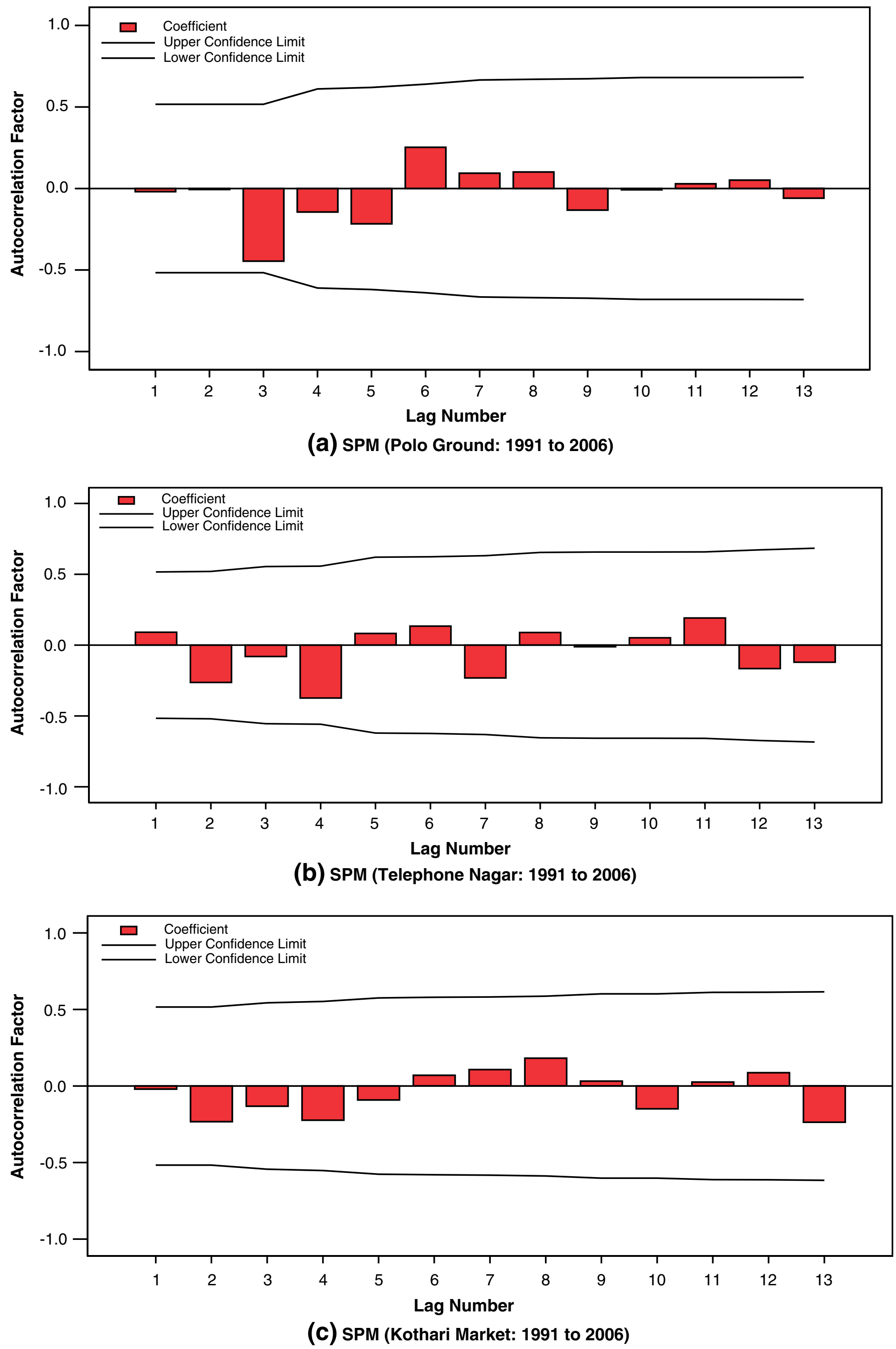
**Fig. 2** A rare-delight of house sparrow sight due to increasing profile of anthropogenic toxicants and temperature

**Table 1** A comparative analysis of trees life-span and temperature (April 2006 and 2007)

| Tree type | Average age | Approximately reduced age | Exactly reduced age | April | 2006 | 2007 |
|---|---|---|---|---|---|---|
| Pipal | 400 | 150–200 | 175 | 6th | 39.0 | 42.0 |
| Neem | 100 | 70–80 | 75 | 5th | 37.7 | 40.0 |
| Bargad | 1,000 | 700–800 | 775 | 4th | 37.7 | 38.4 |
| Mango | 100 | 75 | 75 | 3rd | 38.0 | 39.2 |
| Mahua | 150 | 100 | 100 | 2nd | 38.1 | 39.3 |

The remarkable success of the above simple "Simulation Model" is that with tall stacks much of the total impact

**Fig. 3** Annual autocorrelation emission factor (EF) analysis for SPM on air quality **a** Polo-Ground **b** Telephone-Nagar **c** Kothari-Market (1991–2006)




occurs in regions sufficiently far from the source with conditional parametric variations as per area-wise study regions like (a) Polo-Ground (b) Telephone-Nagar (c) Kothari-Market (1991–2006), respectively (Figs. 3, 4, 5). Parametric models that allow for over-dispersion parameter ($f_2 = 1.397$) and autocorrelation, up to fourth order, did not differ substantially. Autocorrelation was low and what remained was probably due to inflexible control of seasonality. The above "Simulation Model" has provided biased estimates because mostly the health outcomes are non-normally distributed. When linear and Poisson models were compared, estimates of all pollutants SPM, $SO_2$, and $NO_X$ showed noticeable differences. This could be due to the dependent variable was clearly non-normally distrib-

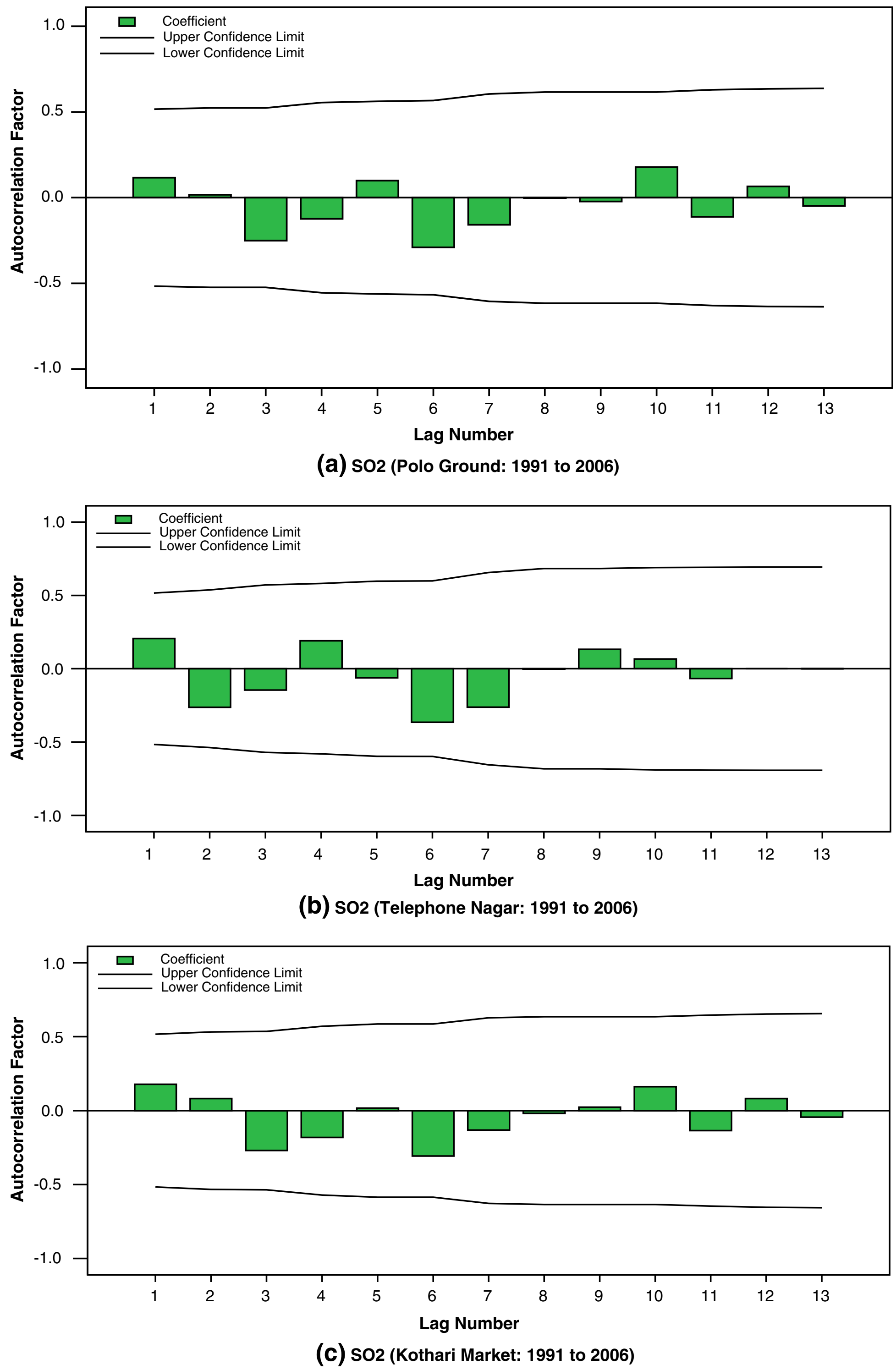



**Fig. 4** Annual autocorrelation emission factor (EF) analysis for $SO_2$ on air quality **a** Polo-Ground **b** Telephone-Nagar **c** Kothari-Market (1991–2006)

uted with a small range of variation. The relationships between air pollutants using different statistical models were included at same time in the regression model. The combinations of best fit lags are found to be (6, 10, 12) for the (SPM, $SO_2$, $NO_X$) multi-pollutant respectively (Figs. 3a, 4a, 5a). The different models lead to different estimates and care is needed in their interpretation and careful reporting, making it clear how variables have been modeled. If trends and seasonality have been well parameterized in a Poisson autoregressive model, results should not differ substantially from those obtained through by using generalized additive models (Tobias et al. 1999; Samoli et al. 2001) for smoother scatter-plot (Figs. 3, 4, 5) to observe SPM, $SO_2$ and $NO_X$ pollutants.

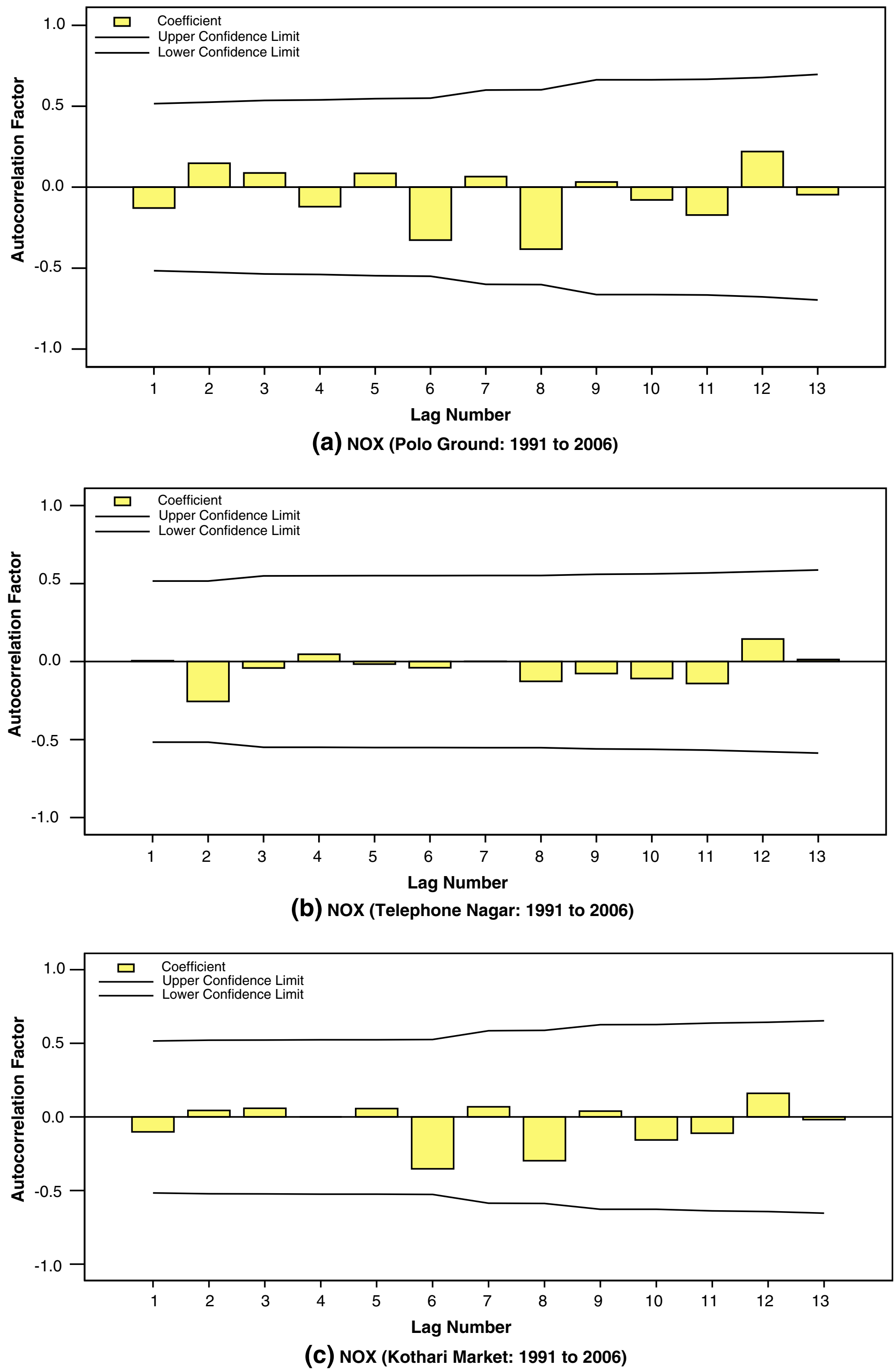



**Fig. 5** Annual autocorrelation emission factor (EF) analysis for $NO_X$ on air quality **a** Polo-Ground **b** Telephone-Nagar **c** Kothari-Market (1991–2006)

**Acknowledgments** The authors are grateful to Government of India's DST, New Delhi, Fast Track Proposal for Young Scientists (Earth and Atmospheric Sciences), which sponsored the project entitled "A Systems Approach for Managing Air Quality in an Urban Area" at S.F.S.P., Devi Ahilya University, Indore (MP), India. Thanks are also due to all other authors of respective universities/organizations for making contributions in the study.

## References

Adachi K, Tainosho Y (2004) Characterization of heavy metal particles embedded in tire dust Environ Int 30:1009–1017

CPCB (1995) Ambient air quality status. Central Pollution Control Board, New Delhi

Katz M (1977) Standard methods for air sampling and analysis, 2nd edn. APHA, Spring Field

Manahan SE (1994) Environmental chemistry. CRC Press, Boca Raton

Putaud J, Raes F, Van Dingenen R, Brüggemann E, Facchini M, Decesari S, Fuzzi S, Gehrig R, Hüglin C, Laj P et al (2004) A European aerosol phenomenology 2: chemical characteristics of particulate matter at kerbside, urban, rural and background sites in Europe. Atmos Environ 38: 2579–2595

Rodriguez S, Querol X, Alastuey A, Viana M, Alarcon M, Mantilla E, Ruiz CR (2004) Comparative PM10–PM2.5 source contribution study at rural, urban and industrial sites during PM episodes in Eastern Spain. Sci Tot Environ 328: 95–113

Samoli E, Schwartz J, Wojtyniak B, Touloumi G, Spix C, Balducci F, Medina S, Rossi G, Sunyer J, Bacharova L, Anderson HR, Katsouyanni K (2001) Investigating regional differences in short-term effects of air pollution on daily mortality in the APHEA project: a sensitivity analysis for controlling long-term trends and seasonality. Environ Health Prospect 109: 349–353

Tobias A, Sunyer J, Samoli E, Katsouyanni K (1999) Contaminacion ambiental y mortalidad. Analisis de sensibilidad. Gac Sanit 13:73

Van Dingenen R, Raes F, Putaud J, Baltensperger U, Charron A, Facchini M, Decesari S, Fuzzi S, Gehrig R, Hansson H (2004) A European aerosol phenomenology 1: physical characteristics of particulate matter at kerbside, urban, rural and background sites in Europe. Atmos Environ 38: 2561–2577