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# Airborne Toxic Metals in Air of Mumbai City, India

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Recent concern about health effect of air pollution has focused on Respirable Suspended Particulate Matter (RSPM) concentration due to increased mortality and morbidity (Dockery and Papes 1994) and asthma (Anderson et al. 1992). The recent study has experienced that road transport to be a major source of RSPM with other significant contribution from power plant, combustion plant process and non-combustion process in addition to road dust, refuse burning and marine aerosol (Chow et al. 1994). It is experienced that the toxic metals are found to be associated with fine dust of urban cities and their harmful effects are well documented. During last two decades, several studies have been reported on elemental composition of suspended particulate matter and their effect on exposure population. Status of airborne metals in air environment in India and various strategic approaches for air management of air pollution have been reported (Gajghate and Hasan 1995; 1996; 1999). Recently, it is observed that RSPM concentration in air environment of urban centres is found to be exceeding the WHO guideline. This experienced the serious atmospheric pollution problem of faster growing urban cities and indicates significant health problem (NEERI 1994). The fine dust associated with toxic metals remains in urban air for longer duration and also transport to pristine area, causing deterioration of environment.

Mumbai is located on India's' West Coast on a peninsula originally composed of seven islets. The Mumbai metropolitan region covered an area of more than 600 square kilometers. Much of the Mumbai is on a flat plain, one-fourth of which is below sea level. The landuse structure of Mumbai has undergone major changes in past decade. Massive developments have arisen in previously non-urban belts along the western corridor and the Mumbai-Pune rail corridor. Mumbai is India's main industrial city with many air polluting industries. There are approximately 40,000 small and big industries in the city. The total population of Mumbai is about 9.9 million according to 1991 census. Maximum traffic flow at a road section in Mumbai is highest in India. Mumbai, a center of transportation and commercial activities is experiencing high rate of mortality, morbidity and rise in pulmonary diseases. Expansion of industries, increased foundry production and increase in vehicles has led to a severe air pollution problem in the city. In the city of Mumbai, lead along with other toxic metals in Suspended Particulate Matter (SPM) has been observed to be present in the considerable quantities in ambient air (Khandekar et al. 1984; Nambi et al. 1998). There have only been sporadic

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measurements of toxic elements in air environment in Mumbai and information on elements in RSPM is meagre. With this drawback, the study is undertaken for monitoring of RSPM and systematic analysis of elemental composition since 1993-1998 in Mumbai, India. Time series analysis helps in analyzing the data series and enables to take decisions based on the available set of data. The regression model, which considers the effect of annual cycle and linear trend for precipitation chemistry data was used by Buishand et al. (1988). In the frequency domain, Spectral analysis approach was also used for periodic analysis (Sirois et al. 1995). In this paper, trend analysis of toxic metals in RSPM is performed assuming the classical additive model as the representative of concentration data series. The possible significance of four components is also investigated.

## MATERIALS AND METHODS

A network spread over Mumbai city was operated activity zonewise to get entire coverage of ambient RSPM and metal concentrations. For Mumbai City, three sampling sites representing residential, commercial and industrial activity were selected. RSPM were collected from the locations using samplers operated at a rate of 1.5 $m^3$/min for 24 hrs on pre-weighed glass fibre filter of 20x25cm size and reweighed after sampling in order to determine the mass concentration of the particles collected. The concentrations of particulate matter in ambient air were then computed on the net mass collected divided by the volume of sampled. Twelve circles of 1' diameter were punched out from the filter paper and digested in concentrated nitric acid. The content was filtered through Whatman paper No. 42 and final volume made-up to 100 ml by double distilled water. The filtrate was used to determine the metals Cr, Cd, Fe, Pb, Zn and Ni by GBC 900 Atomic Absorption Spectrophotometer. The details of sampling procedure are given elsewhere (Katz 1977). The monthly averages of each metal concentrations was averaged over all three stations during the period from 1993 to 1998 in Mumbai and are presented in this study. Generally, the time-series can be decomposed in to four components, trend, seasonal, cyclical and irregular (Box et al. 1970). A classical additive model is assumed to be representative of the data series, given by,

$$Y_t=T_t+S_t+C_t+R_t$$

where, $Y_t$ is the concentration series, $T_t$ is the trend, $S_t$ is the seasonal, $C_t$ is the cyclical term and $R_t$ is the random component

Seasonal component is calculated by moving average method and then subtracted from original time series. After removing the seasonal effects, it is essential to test for the significance of cyclical effect and trend component. A regression equation, which takes in to account the trend, cycle and irregular term, is used, given by,

$$u_t=a_0 + a_1 \cos(wt) + a_2 \sin(wt) + bt + R_t \qquad (1)$$

Where, $u_t$ is the deseasonalised series, $a_0$, $a_1$, $a_2$, b are the coefficients of the equation and can be determined by ordinary least square technique, w be the frequency of oscillations and $w=2\pi/T$ (T is the period of oscillations), bt represents the trend component, $a_o$ is the constant term represents the overall mean. The sine cosine term represents the cyclical component. Equation (1) can also be written as,

$$u_t=a_0 + a\cos(wt+\phi) + bt + R_t \quad (2)$$

Where, a is the resultant amplitude, $a=\mathrm{sqrt}(a_1^2+a_2^2)$, $\phi$ is the phase angle, $\phi=\tan^{-1}(a_2/a_1)$

The significance of trend can be determined by using student's t-statistics given by,

$t = \mathrm{est}(b)/\sigma_{est(b)}$ , where, $\sigma_{est(b)}$ is the standard error of est(b)

When the statistics t tends to deviate from zero, it means that there is a presence of trend.

The presence of cyclical component has been determined by testing the significance of the coefficients $a_1$ & $a_2$ using F-test with the null hypothesis that $a_1=0$ & $a_2=0$. If the coefficients are significant, the next step is to determine the period of the cycle. For this, following procedure has been used.

Let $a_1=(\Sigma u_t*\cos wt)/ (\Sigma\cos^2 wt)$, $a_2=(\Sigma u_t*\sin wt)/ (\Sigma\sin^2 wt)$

Let us write $R_T^2=a_1^2+ a_2^2$, where $R_T^2$ is the intensity of the period T.

Number of trial period's say $\lambda$ round about the true period T, which may be guessed by plotting the data on a graph paper and calculate $R_T^2$ in each case. Finally, a graph plotting $R_\lambda^2$ against $\lambda$ is drawn. The value of $\lambda$ for which $R_\lambda^2$ attains a maximum is the true period. Similarly, if the cyclical component is composed of several periodic terms, $R_\lambda^2$ will remain small unless the trial period $\lambda$ coincides with one of the true periods, in which case it attains a local maximum with value equal to the square of amplitude of the periodic term concerned.

## RESULTS AND DISCUSSIONS

RSPM monitoring was carried out at industrial, commercial and residential sites during the study period in Mumbai. The study revealed that monthly average of RSPM level ranged from 36 to 437 $\mu g\ m^{-3}$ at industrial, 37 to 270 $\mu g\ m^{-3}$ at commercial and 34 to 262 $\mu g\ m^{-3}$ at residential site. The profile of annual average of RSPM was 195-231 $\mu g\ m^{-3}$, 94-194 $\mu g\ m^{-3}$ and 90-120 $\mu g\ m^{-3}$ at industrial, commercial and residential sites respectively. The levels of RSPM is high at Mumbai and exceeded the WHO standards at all sampling locations. Shah and Nagpal (1997) reported the high concentrations of RSPM. Exposure to RSPM in 1982 was much higher than WHO air quality guidelines. The road traffic, resuspension of road dust, domestic refuse burning and furnace oil used in industries are largest sources of PM10 emission. These sources at low height therefore contribute significantly to population exposure. The monthly averaged concentrations of six metals are delineated in Fig.1a through Fig.1f. It can be observed that the concentration of Cd ranged from 0.001$\mu g\ m^{-3}$ to 0.06 $\mu g\ m^{-3}$. However, the highest concentration as 0.061$\mu g\ m^{-3}$ was recorded in the month of April 1997. The annual average measurement of Cr ranged from 0.008 $\mu g\ m^{-3}$ to 0.08 $\mu g\ m^{-3}$ with monthly level of Cr varied from 0.001 $\mu g\ m^{-3}$ to 0.18 $\mu g\ m^{-3}$ during the study period is recorded. The measurement of monthly concentrations of ambient Ni varied from 0.008 $\mu g\ m^{-3}$ to 0.37 $\mu g\ m^{-3}$. The highest concentration

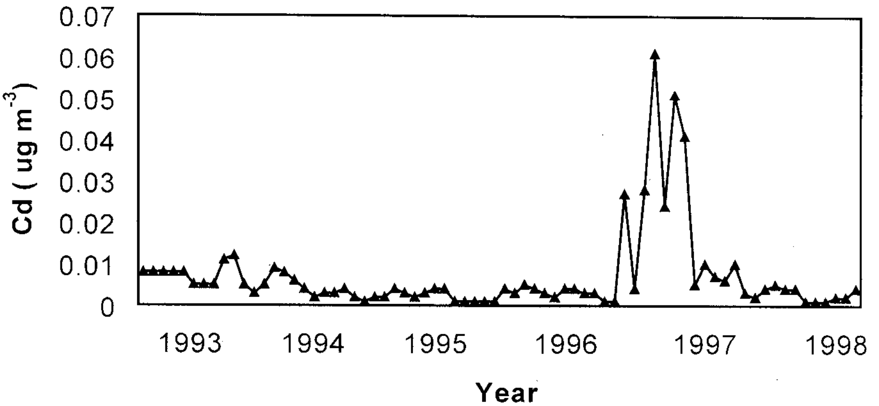

**Figure 1a.** Ambient Cadmium concentrations observed at Mumbai

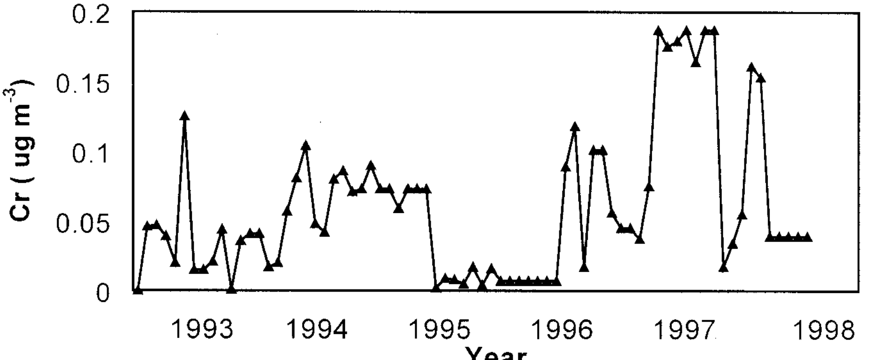

**Figure 1b.** Ambient Chromium concentrations observed at Mumbai

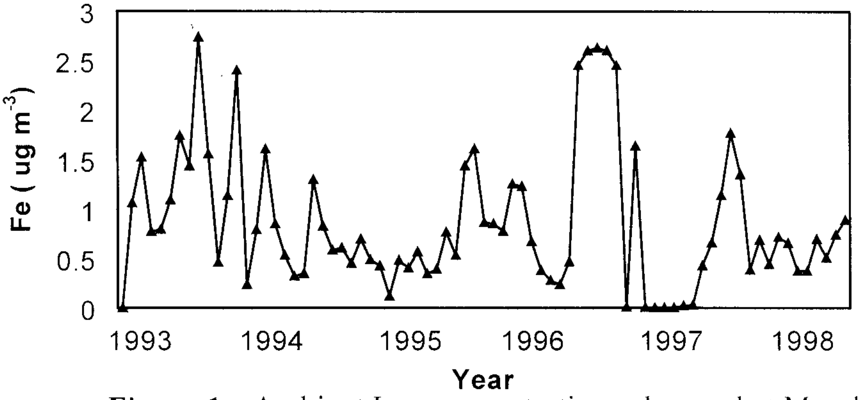

**Figure 1c.** Ambient Iron concentrations observed at Mumbai

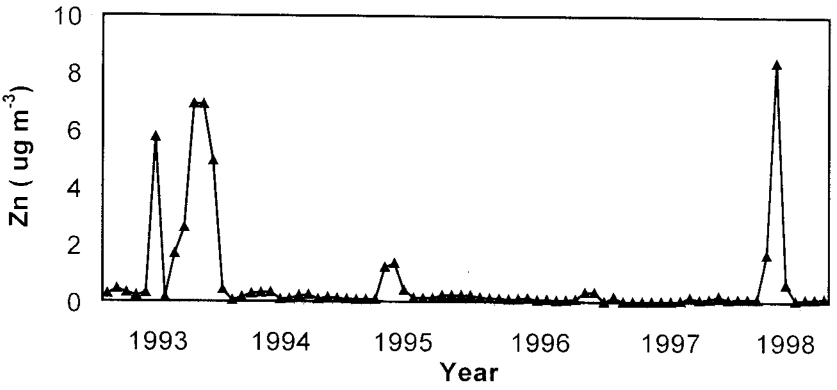


**Figure 1d.** Ambient Zinc concentrations observed at Mumbai

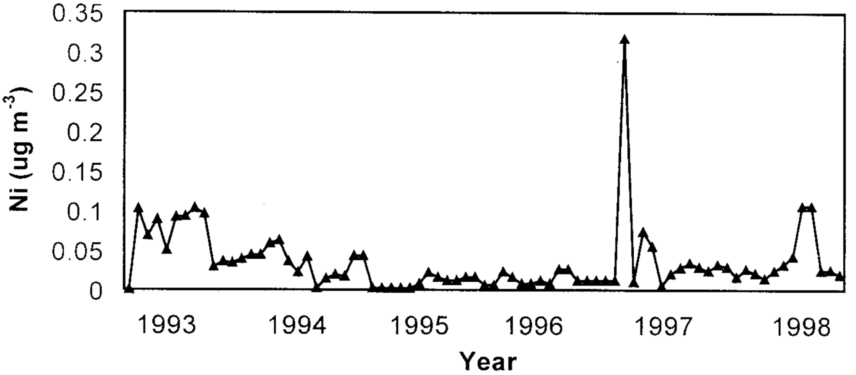


**Figure 1e.** Ambient Nickel concentrations observed at Mumbai

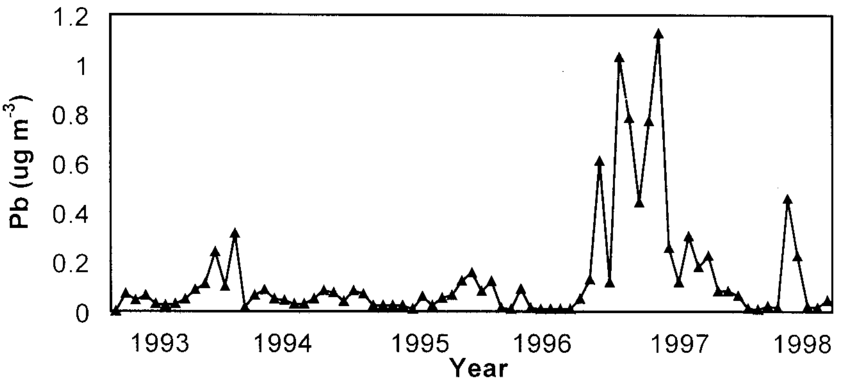


**Figure 1f.** Ambient Lead concentrations observed at Mumbai

as 0.37μg $m^{-3}$ was recorded in May 1997. The annual average Ni levels varied from 0.01 μg $m^{-3}$ to 0.069 μg $m^{-3}$ is observed during the study period. The monthly averaged zinc and iron concentrations ranged from 0.09 μg $m^{-3}$ to 2.53 μg $m^{-3}$ and 0.28 μg $m^{-3}$ to 1.39 μg $m^{-3}$ respectively. The highest concentration of zinc as 8.4μg $m^{-3}$ is recorded in November 1998. The highest concentration of Fe was about 2.7 μg $m^{-3}$ in August 1993. Lead measurement indicates that it is significant pollution in Mumbai. The monthly Pb levels ranged from 0.08 μg $m^{-3}$ to 1.17 μg $m^{-3}$ has observed. The values exceeded the WHO guidelines (0.5 - 1.00 μg $m^{-3}$) in winter. Autoexhaust is the major contribution to the atmospheric lead in Mumbai that lead to hypertension and kidney disease in adults, and lower IQ in children (Mathur et al. 1998).

The trend analysis for metals was carried out using the decomposition method as described above. The results are delineated in Table1. For cadmium and chromium no significant trend was detected. However this should be investigated further by including the structural break variable in the Equation (2).

**Table 1.** Trend analysis of metals observed in Mumbai during 1993-1998

| Concentration | $\bar{y}$ | est a | $\sigma_a$ | b | $\sigma_e$ | $\sigma_b$ |
|---|---|---|---|---|---|---|
| Cd | 0.007 | 0.008 | 0.001 | 0.009 | 0.011 | 0.057 |
| Cr | 0.061 | 0.032 | 0.008 | 0.026 | 0.054 | 0.212 |
| Pb | 0.044 | 0.142* | 0.037 | 0.414* | 0.226 | 1.093 |
| Zn | 0.707 | 0.967* | 0.284 | -2.217* | 1.711 | 8.268 |
| Ni | 0.035 | 0.023 | 0.007 | -0.047* | 0.044 | 0.214 |
| Fe | 0.867 | 0.096 | 0.117 | -0.798* | 0.708 | 3.42 |

:* - Significant at 5% level of significance

While observing the seasonal component (Fig. 2a & Fig. 2b), peaks in November and February are observed with troughs in March. Iron, Zinc and Nickel are found to be exhibiting decreasing trend with magnitude -54.43% $y^{-1}$, -30% $y^{-1}$ and -4.6% $y^{-1}$ respectively. For these three metals, the peaks in December and troughs in April are observed (Fig. 2c through 2e). While observing the trends in lead data series, it is increasing with the average magnitude of 50 % $y^{-1}$. This may be due to increased vehicular activities in Mumbai. Though the use of unleaded petrol is recommended and is in effect from 1995, lead is still a pollution problem in Mumbai. A same seasonal pattern is observed for lead also (Fig. 2f). In general, the concentration of all six metals is higher in the dry season (Nov - April) than during the monsoon (July - Oct). This reflects the effect of increased washout of ambient fine dust decreased resuspension from the ground and also increased wind speed and turbulence causing dispersion during the monsoon. The significance of coefficient $a_1$ and $a_2$ indicates the presence of cyclical component. It can be observed from Table 1 that the $a_1$ is significant only for lead and zinc. To find the period of cycle, the trial periods $\lambda_i$'s, i=1,2,3 ---- are taken such as 4 months, one year, two years and so on. The period with maximum intensity is termed as the period of the cycle. The significant cycle of two years and one year

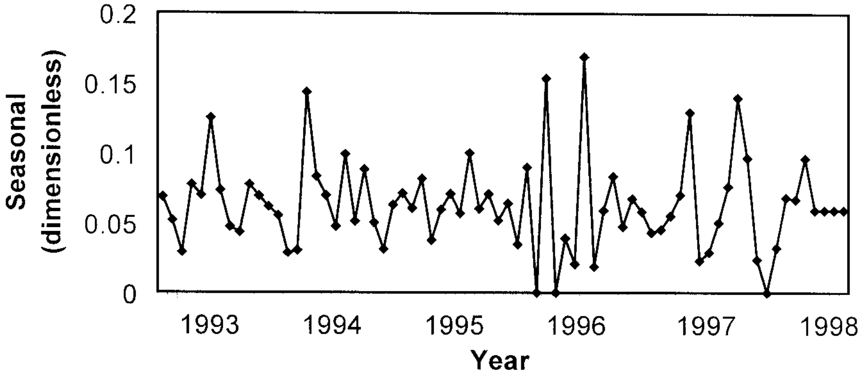


**Figure 2a.** Seasonal variability in Cadmium observed at Mumbai

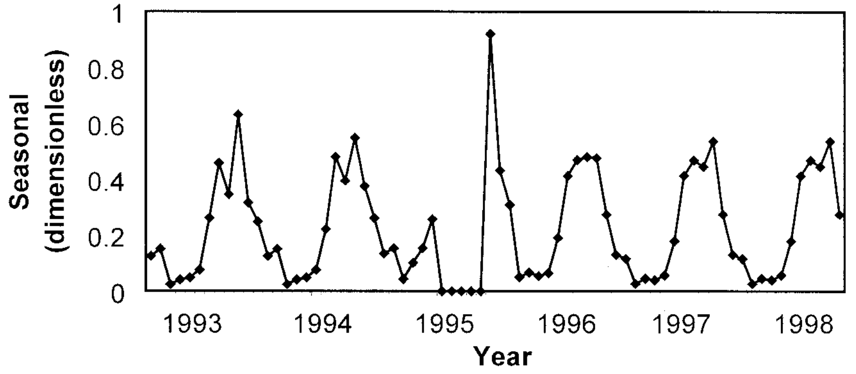


**Figure 2b.** Seasonal variability in Chromium observed at Mumbai

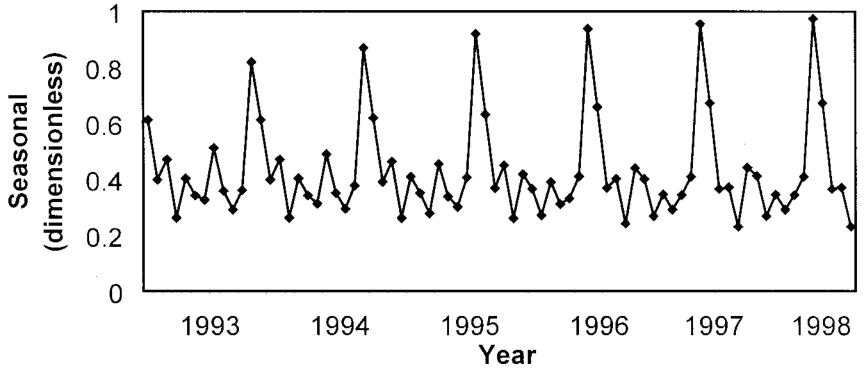


**Figure 2c.** Seasonal variability in Iron observed at Mumbai

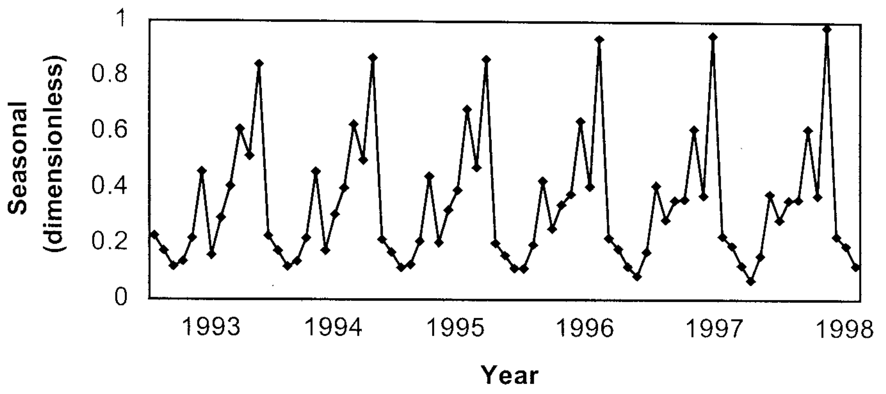


**Figure 2d.** Seasonal variability in Zinc observed at Mumbai

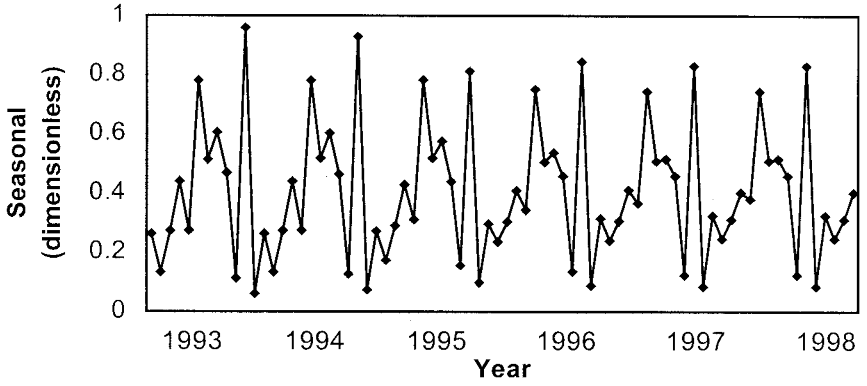


**Figure 2e.** Seasonal variability in Nickel observed at Mumbai

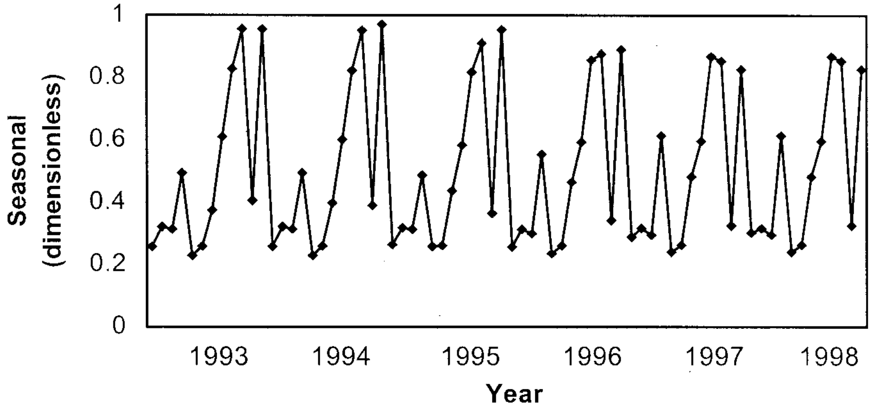


**Figure 2f.** Seasonal variability in Lead observed at Mumbai

is found for lead and zinc respectively. Lead and RSPM are found to be a major pollution problem in Mumbai. Health consequences among exposure indicate that frequent cold, headaches and eye irritation were less common, however cough and hypertension had increased. Similarly while prevalence of bronchitis had decreased, cardiac disease had increased (Shah and Nagpal, 1997). The main contributors of air pollution in Mumbai are transport sector followed by power plants, industrial units and burning of garbage. To arrest this growing problem, a concerted effort on development of stringent standards, the use of latest technologies and effective enforcement is required to prevent from severe effect of pollutants on health.

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