



AIR QUALITY TRENDS IN THE CITY OF COLOMBO

R.N.R.Jayaratne
Senior Environmental Officer
Central Environmental Authority

Prof. O.A.Ileperuma
Senior Lecturer
University of Peradeniya

BRIEF INTRODUCTION



❖ **Two continuous Ambient Air Quality Monitoring Stations were set up in December 1996 at Colombo Municipal Council area under World Bank Funded project called CUTP.**

- to monitor major air pollutants (NO,NO₂,NO_x, SO₂, O₃,CO & PM₁₀)
- with meteorological parameters (WS,WD,VWS, SR,RF,ATE)

One of these monitoring station is located at Colombo Fort Railway station premises and other one was located at Meteorological Department premises.

Met Department one was operated from 1997 to 2000. Colombo Fort one has been in operation since 1997

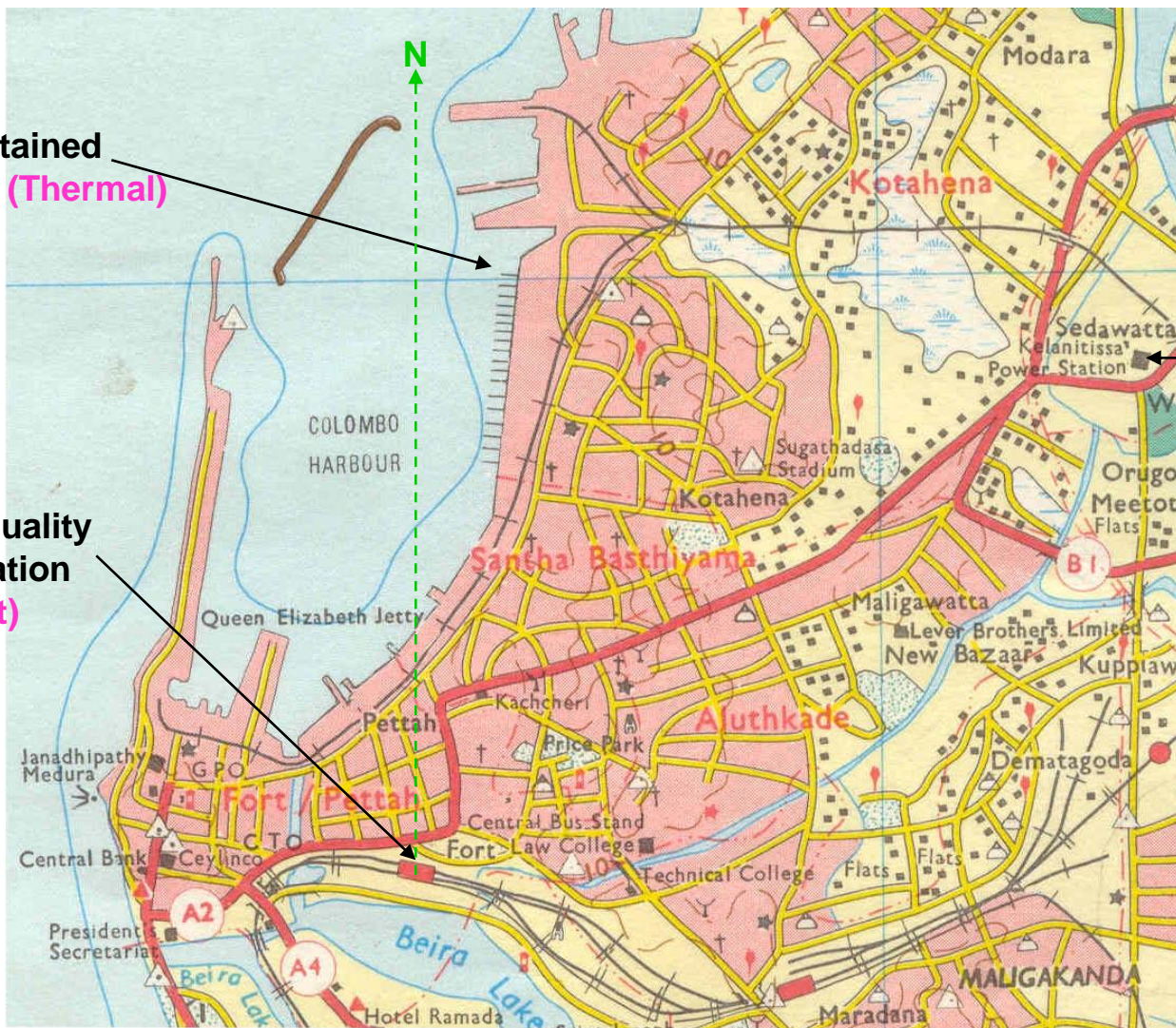
Location of the Colombo Fort Monitoring Station



Barge Mounted Power Plant (Thermal)

Ambient Air Quality Monitoring station (Colombo Fort)

Kelanitissa Power Station (Thermal)





Locations of Two Ambient Air Quality Monitoring Stations

Kelanithissa Power Plant

Barge Mounted Power Plant

Ambient Air Quality Monitoring Station 1 (Colombo Fort Railway Stn)

Ambient Air Quality Monitoring Station 2 (Meteorological Dpt)





Colombo Fort Ambient Air Quality Monitoring Station



Inside of the monitoring station



Monitoring Principles

Ozone

UV Absorption

Carbon Monoxide

Non Dispersive Infra Red
(NDIR)

Nitrogen Oxides

Chemiluminescence

Sulfur Dioxide

UV Fluorescence

PM₁₀

High Volume Sampling



- **Five minute and one hour average concentrations of measured parameters were recorded in data logger.**
- **Every day at midnight an automatic calibration cycle is carried out to check the accuracy and validity of data.**
- **All valid data collected from these two monitoring stations from January 1997 to Dec 2006 were used for this analysis.**



The objectives of this study

- **To identify the trend and variations of major air pollutants for the city of Colombo during the monitoring period.**

(This report will also help to identify gaps in the available information and data requirements for long term monitoring.)

Methodology

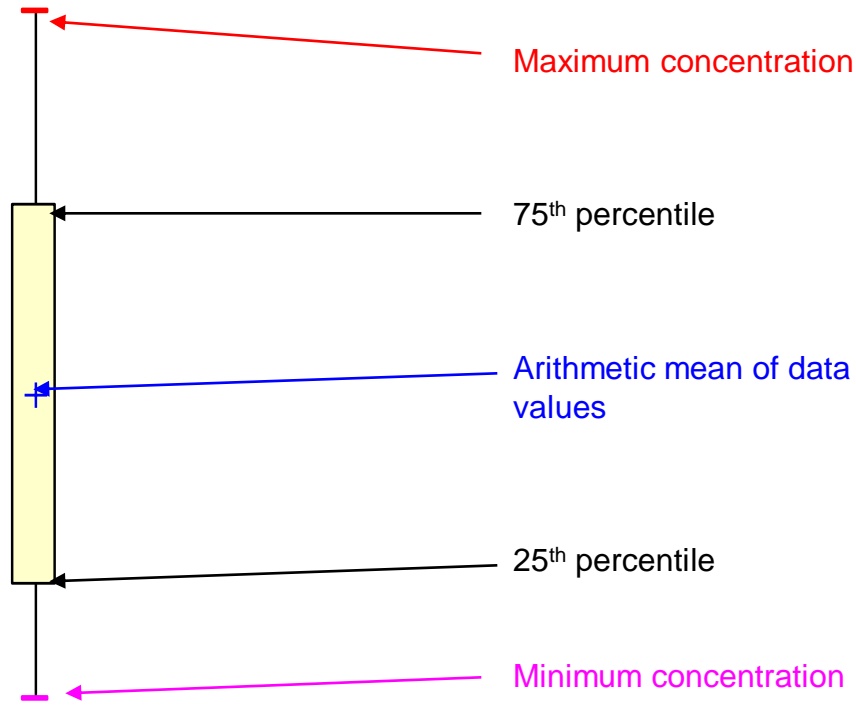


- **Converted all recorded data in binary form in the data logger into digital form by using WINCOLLECT software .**
- **Screened the data base to select good data (Validation) based on daily calibration and instrument errors.**
- **All valid data are presented by diagrams, graphs and tables to identify features and variation patterns easily.**
- **Interpretations are made in scientific manner with recommendations.**

Trends on air pollutants in Colombo

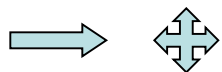
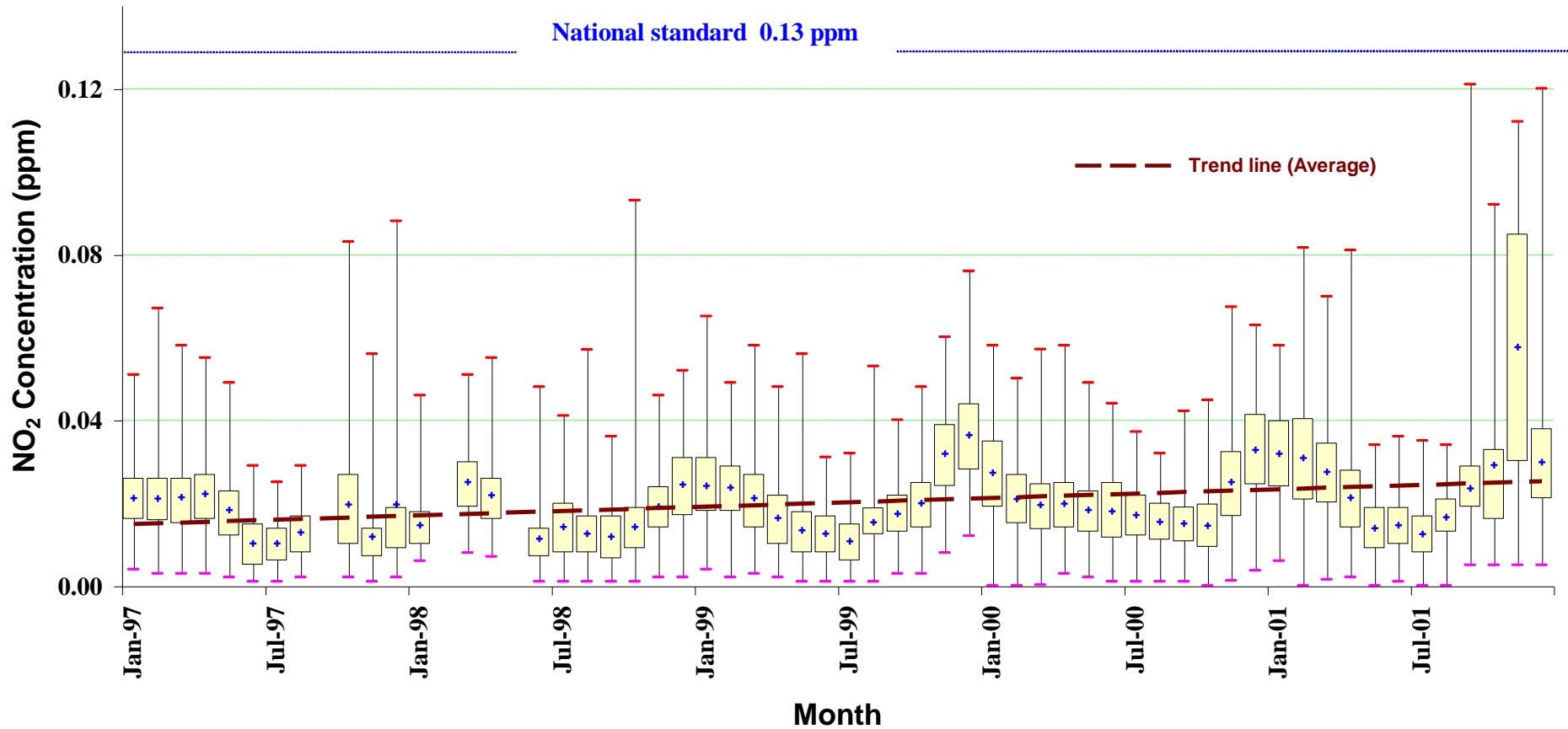


Trend graphs of nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone for both monitoring stations are presented in graphical form and the statistical parameters represented as in the following format.



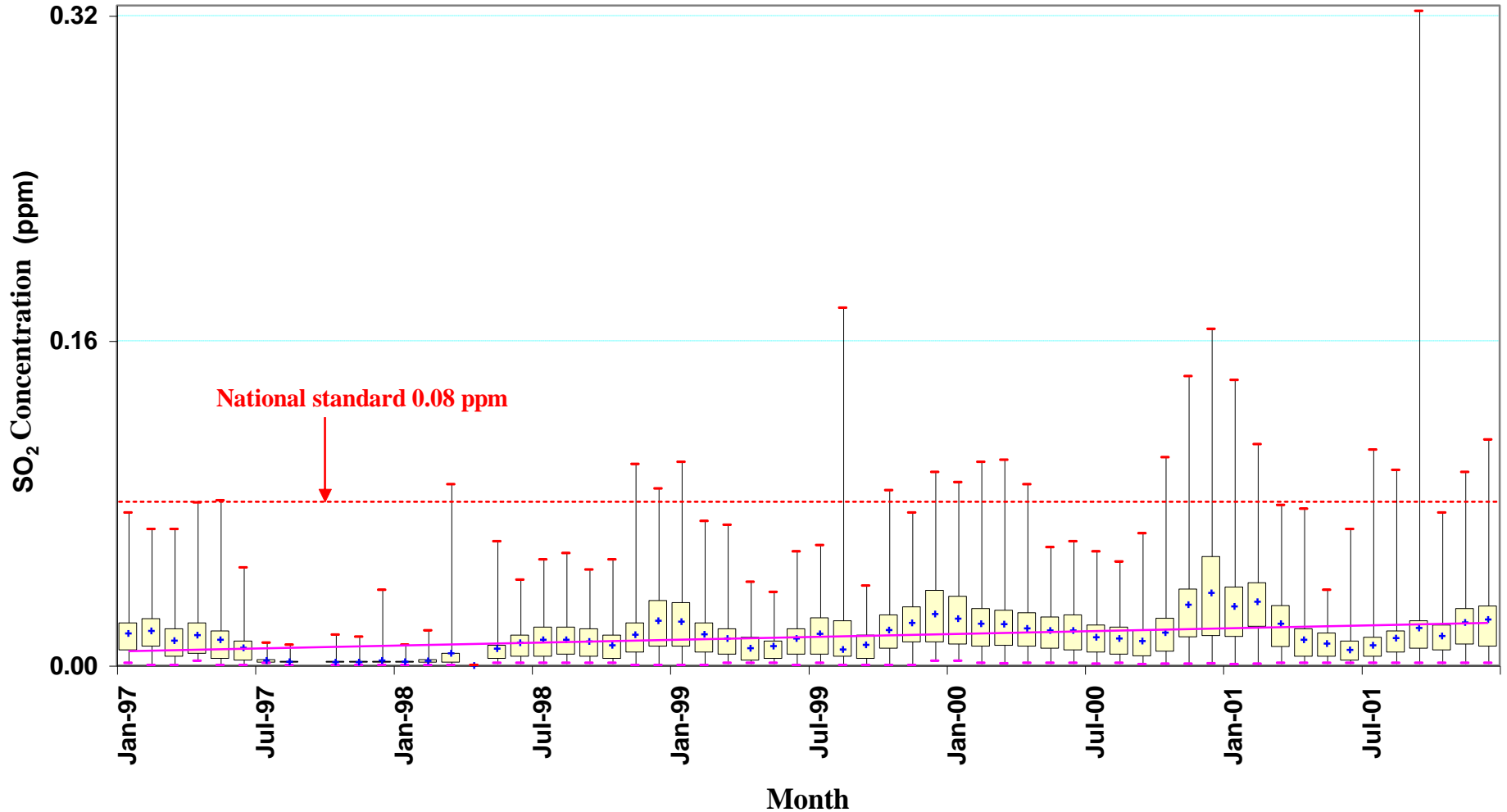


Variation of Nitrogen Dioxide (NO₂) One Hour Average Concentrations at Colombo Fort Ambient Air Quality monitoring station(1997-2001)



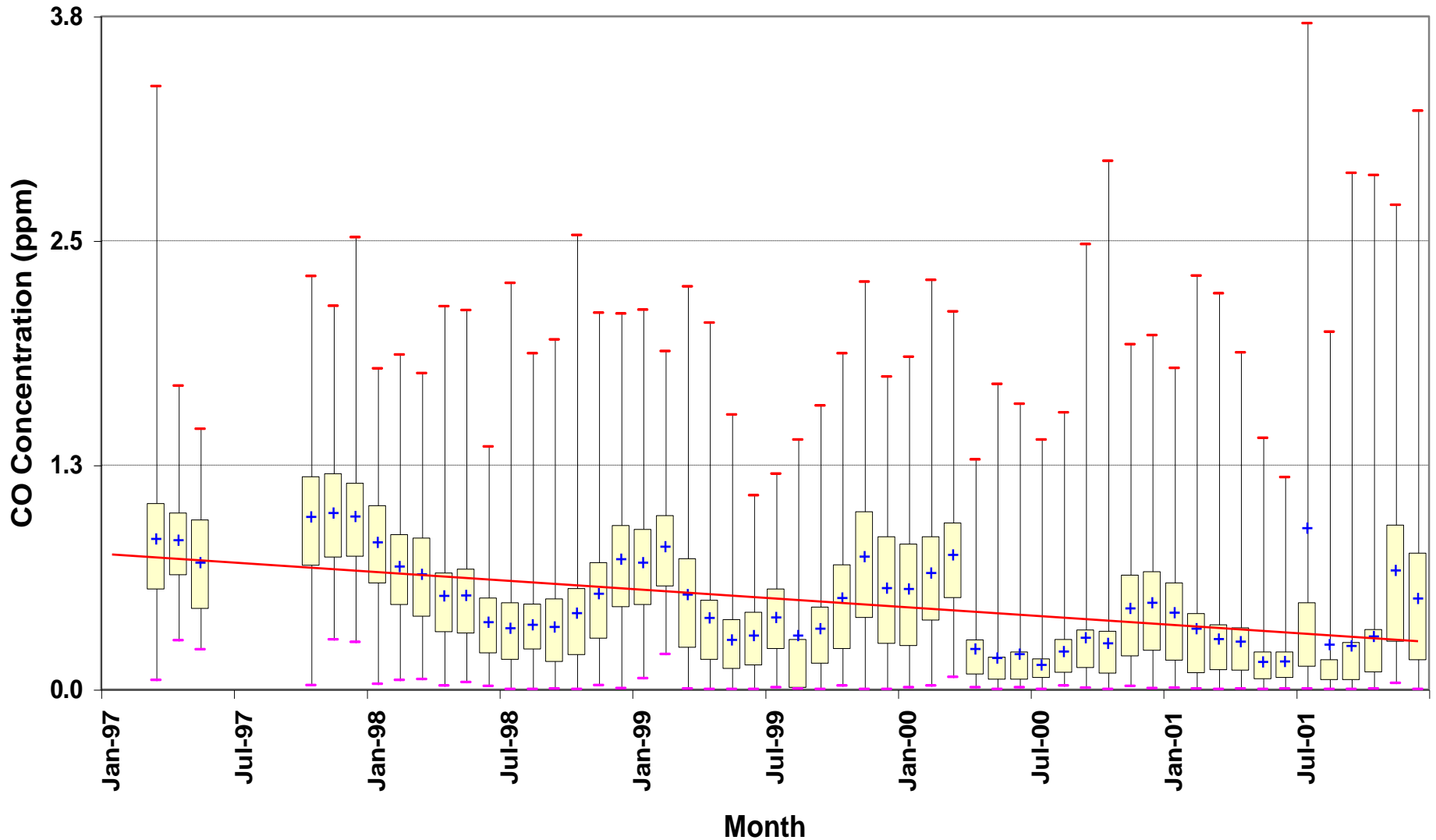


Variation of Sulfur Dioxide (SO₂) One Hour Averages concentrations at Colombo Fort Ambient Air Quality monitoring station

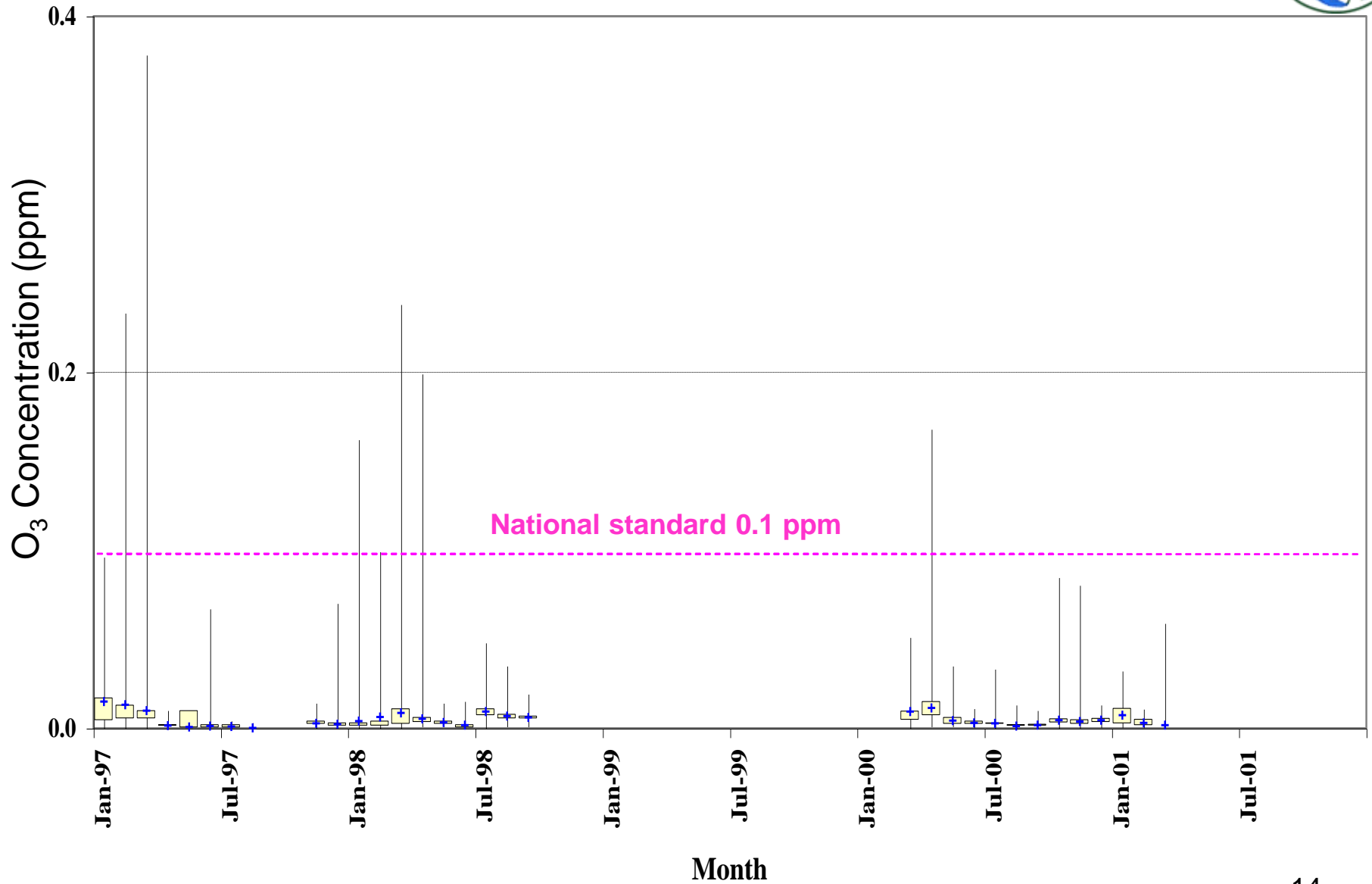




Variation of Carbon Monoxide (CO) One Hour Average Concentrations at Colombo Fort Ambient Air Quality monitoring station (1997-2001)

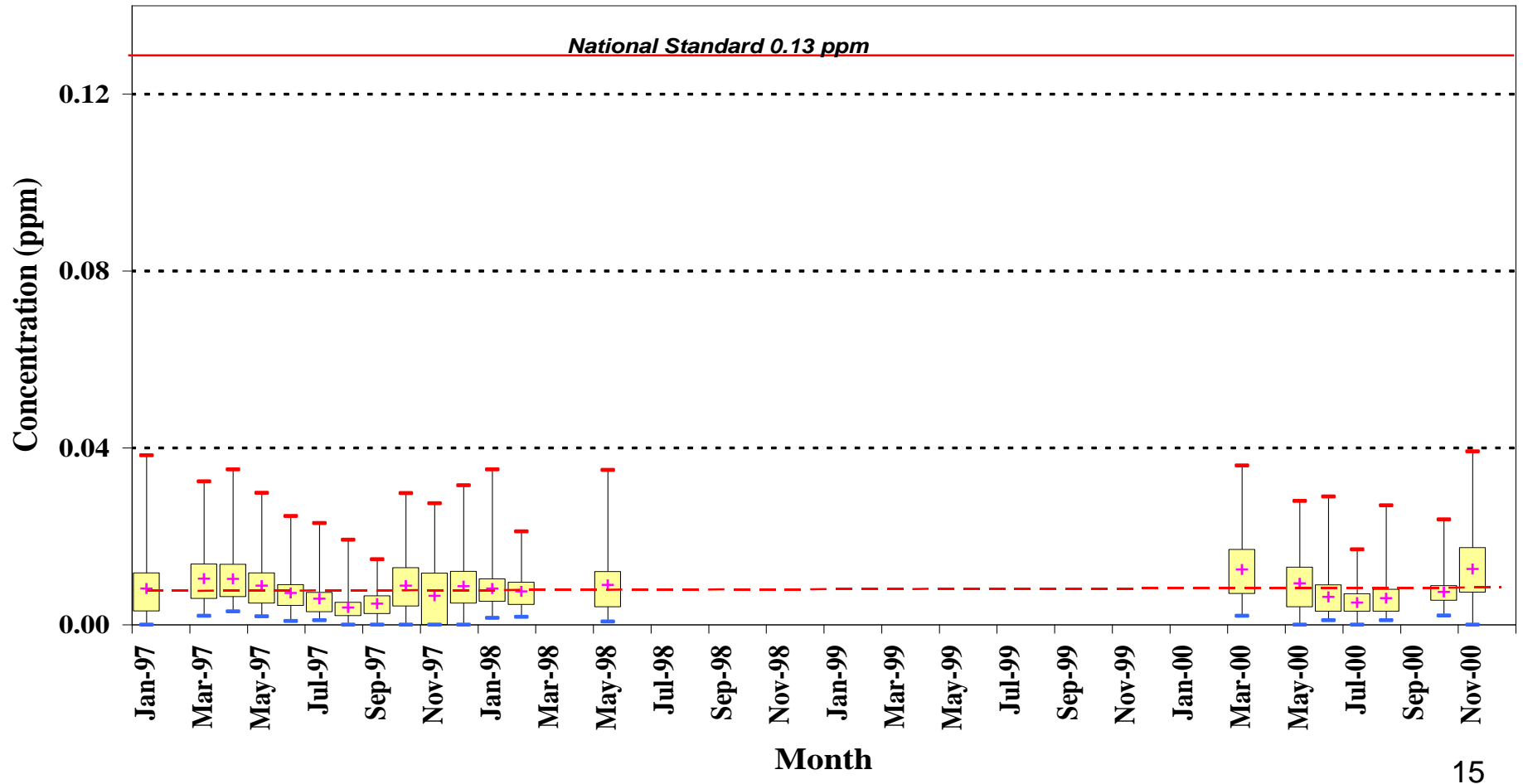


Variation of ozone (O₃) One Hour Average Concentrations at Colombo Fort Ambient Air Quality monitoring station(1997-2001)



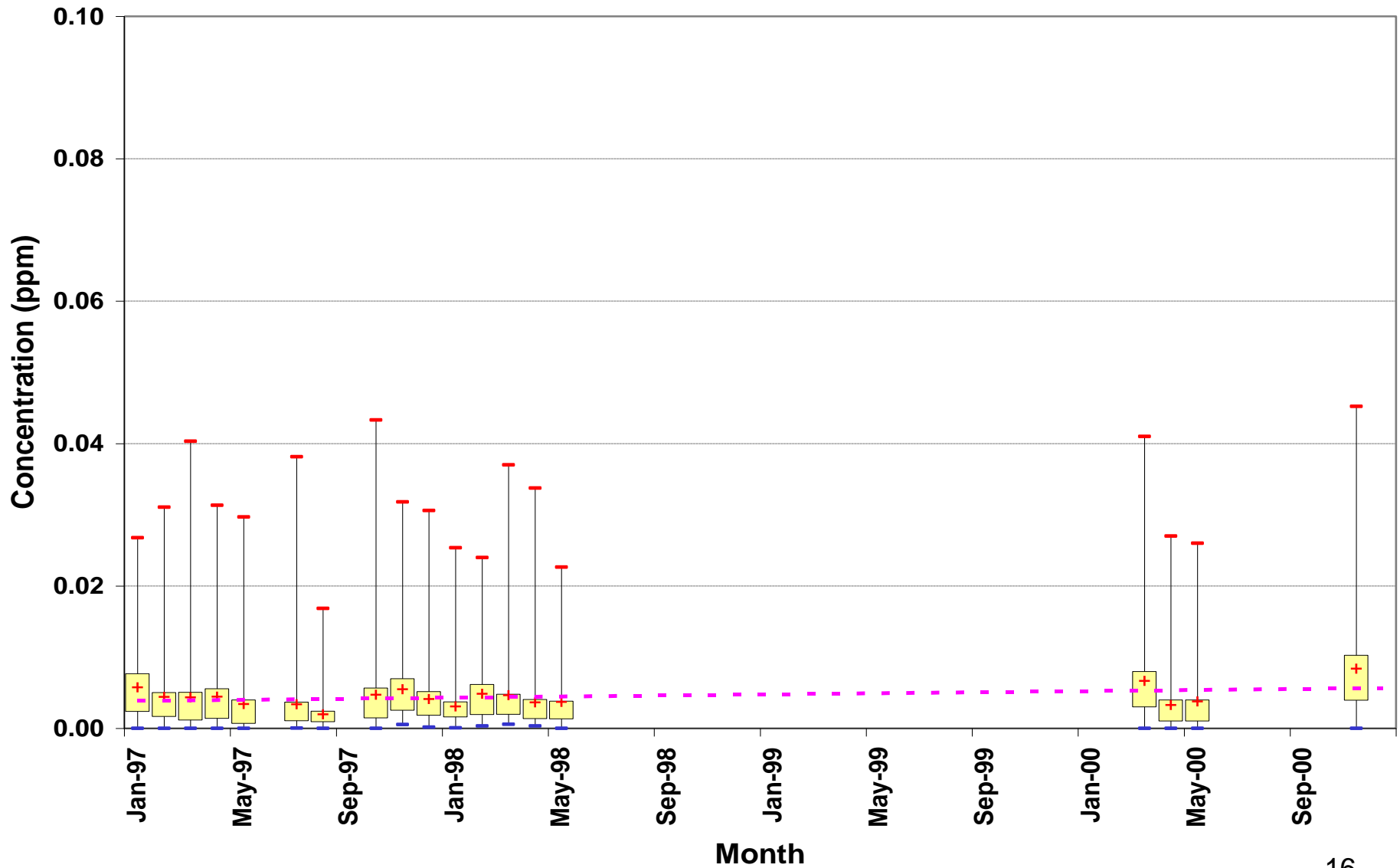


Variation of monthly one hour averages of Nitrogen Dioxide (NO₂) concentrations at Colombo Meteorological Department Air Quality monitoring station (From Jan 1997 to December 2000)

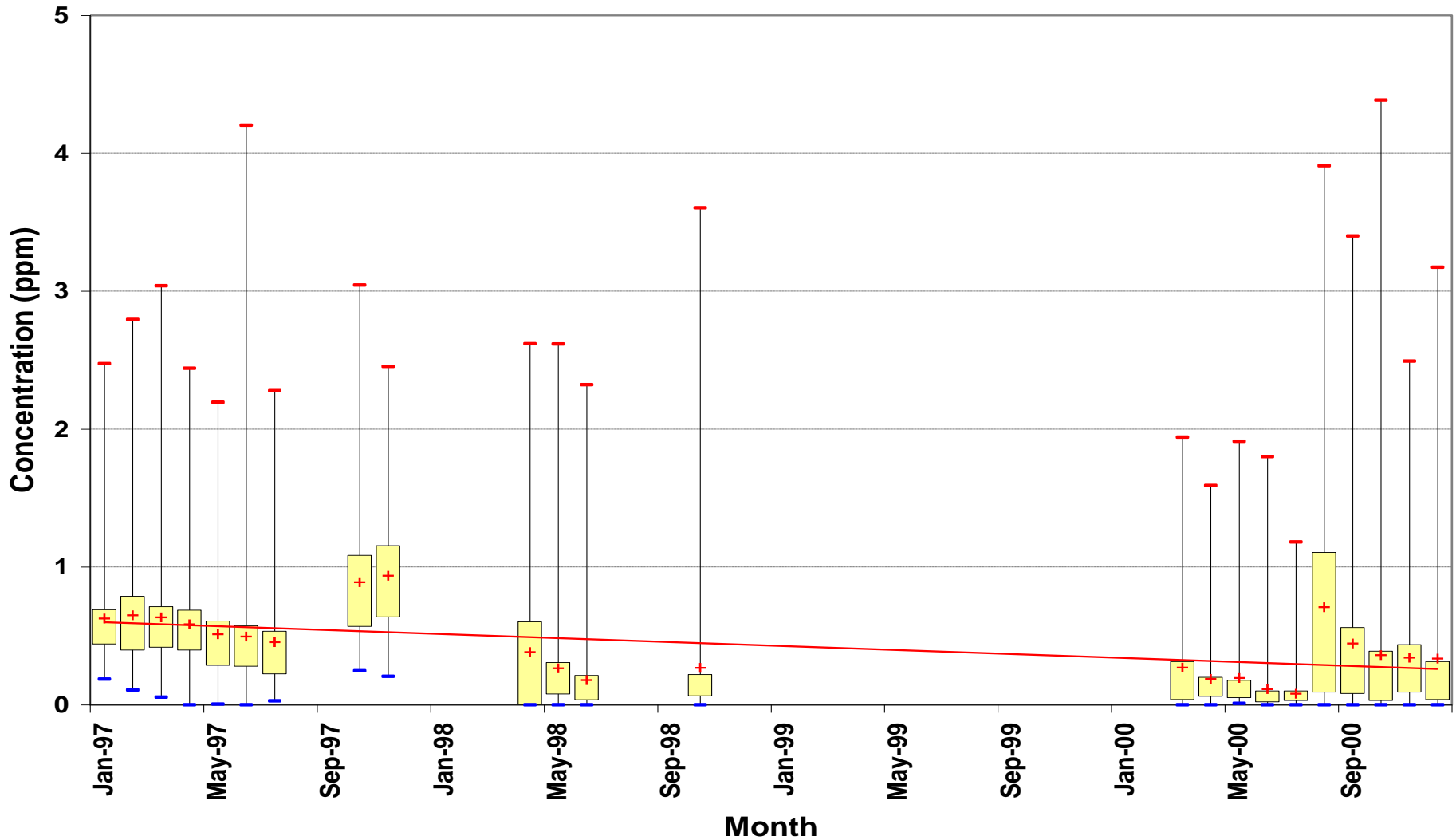




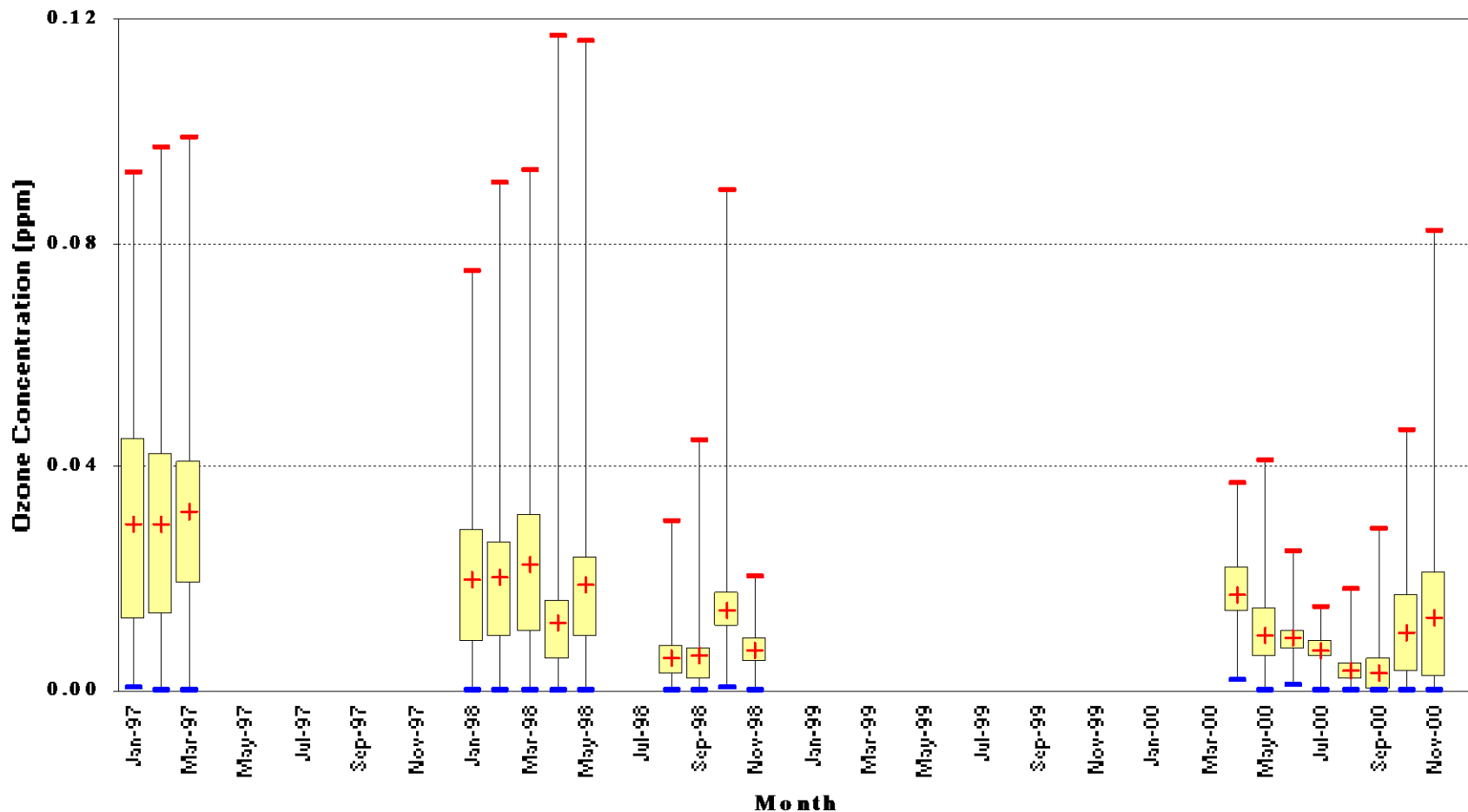
Variation of monthly one hour averages of Sulfur Dioxide (SO₂) concentration:
Colombo Meteorological Department Air Quality monitoring station
(From Jan 1997 to December 2000)



Variation of monthly one hour averages of Carbon monoxide (CO) concentrations at Colombo Meteorological Department Air Quality monitoring station (From Jan 1997 to December 2000)

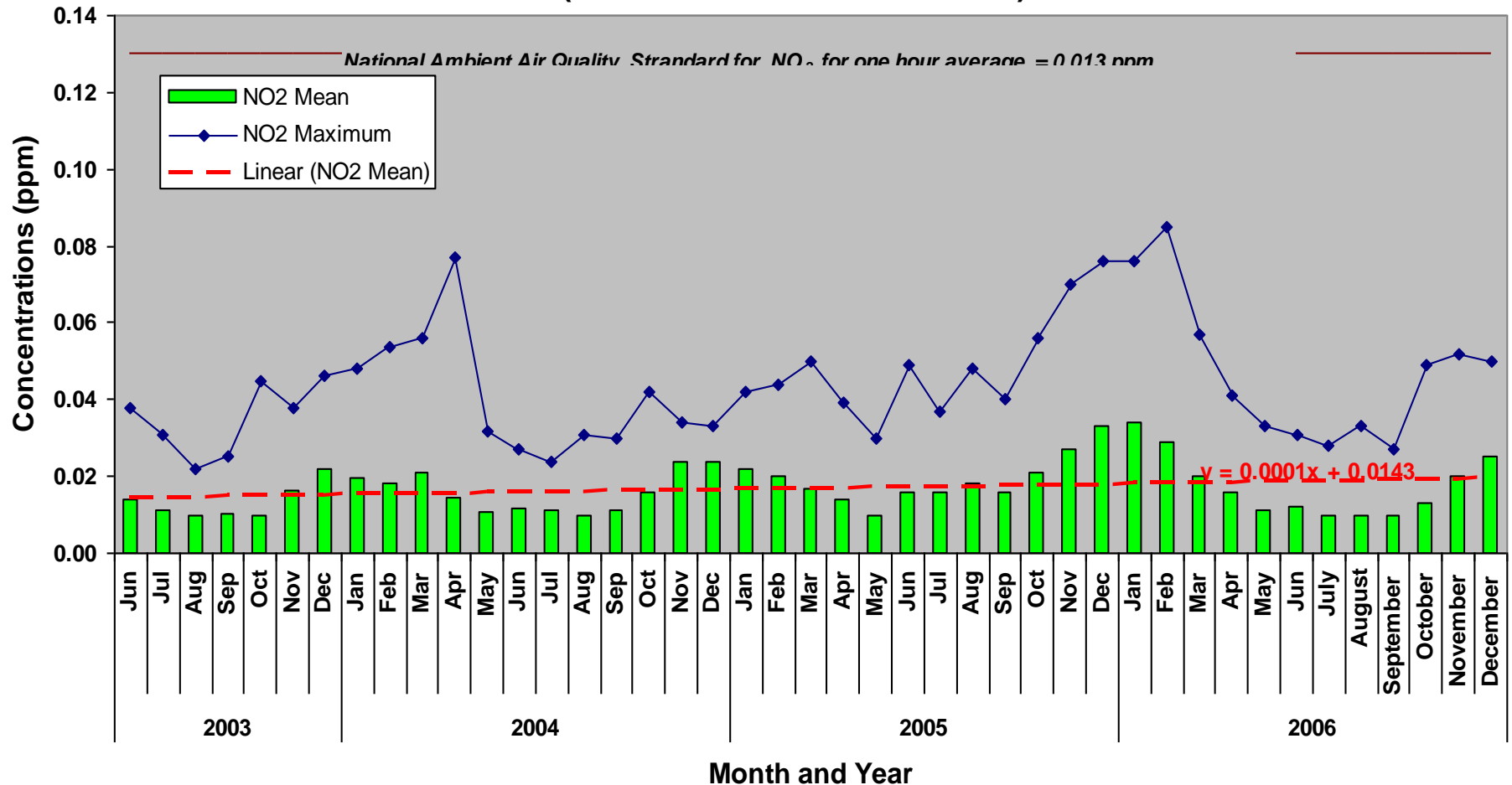


Variation of monthly one hour averages of ozone (O₃) concentrations at Colombo Meteorological Department Air Quality monitoring station (From Jan 1997 to December 2000)

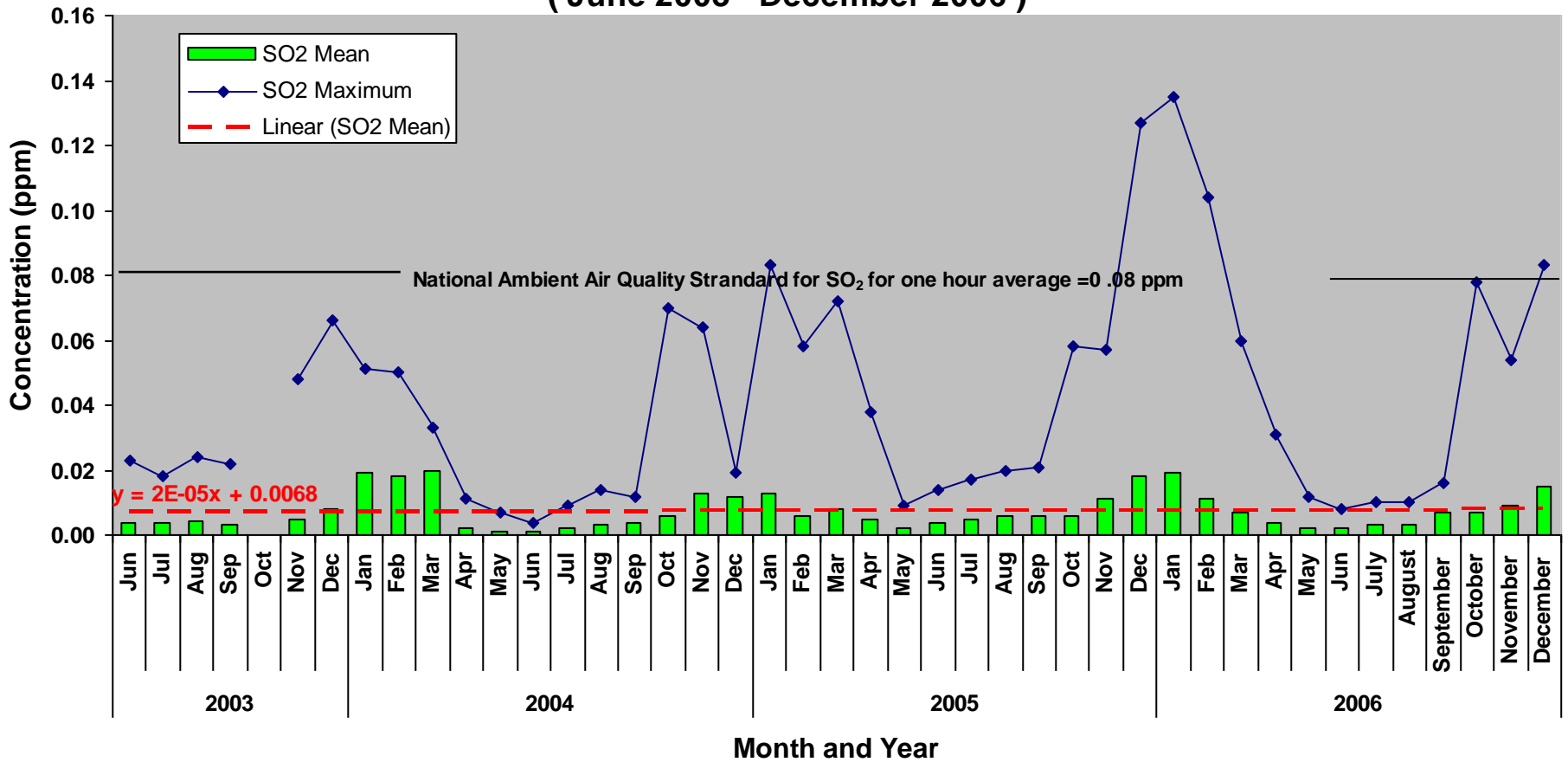




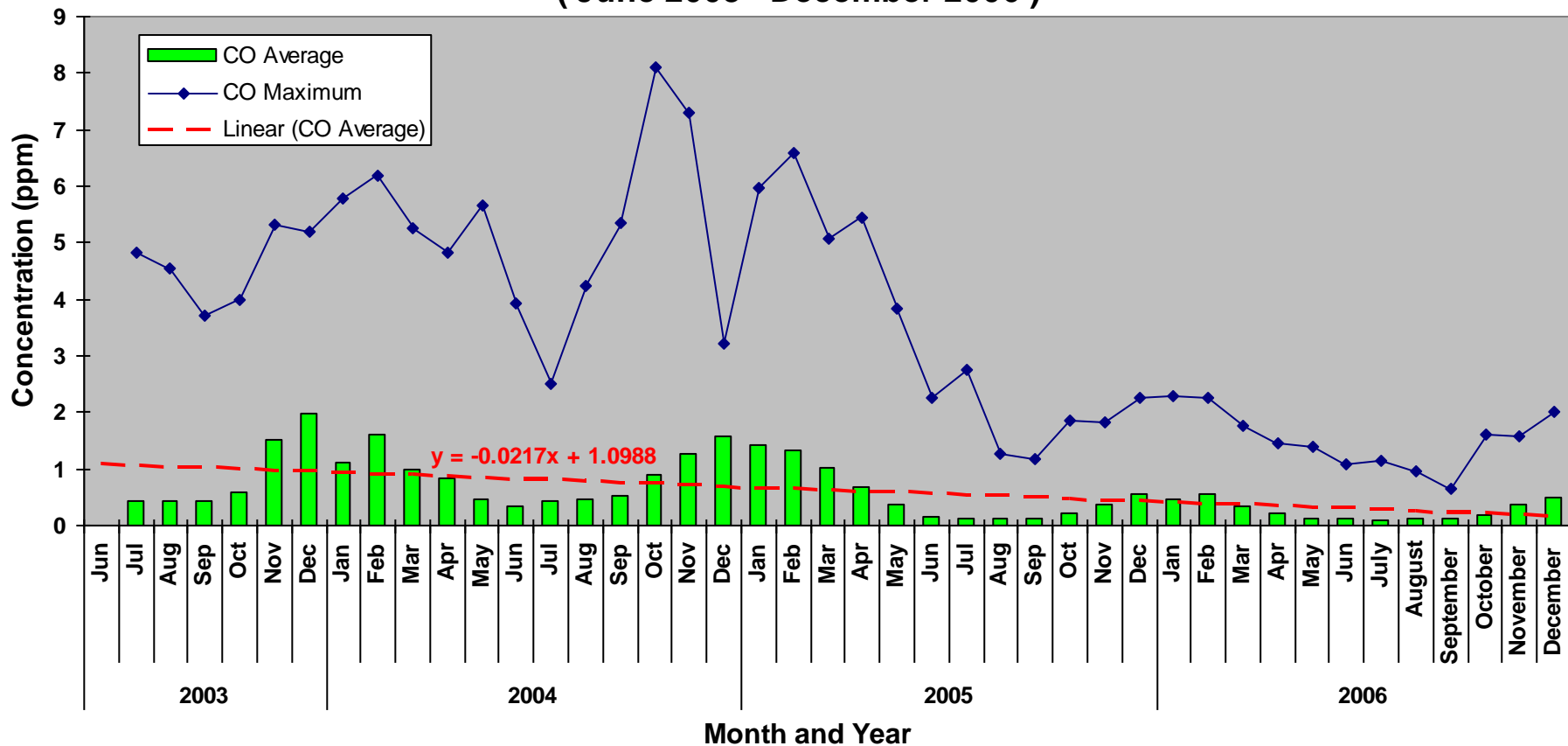
Nitrogen Dioxide Concentration Monthly Mean and Maximum of one hour averages at Colombo Fort (June 2003 - December 2006)



Sulphur Dioxide Concentration Monthly Mean and Maximum of 1 hour averages at Colombo Fort (June 2003 - December 2006)



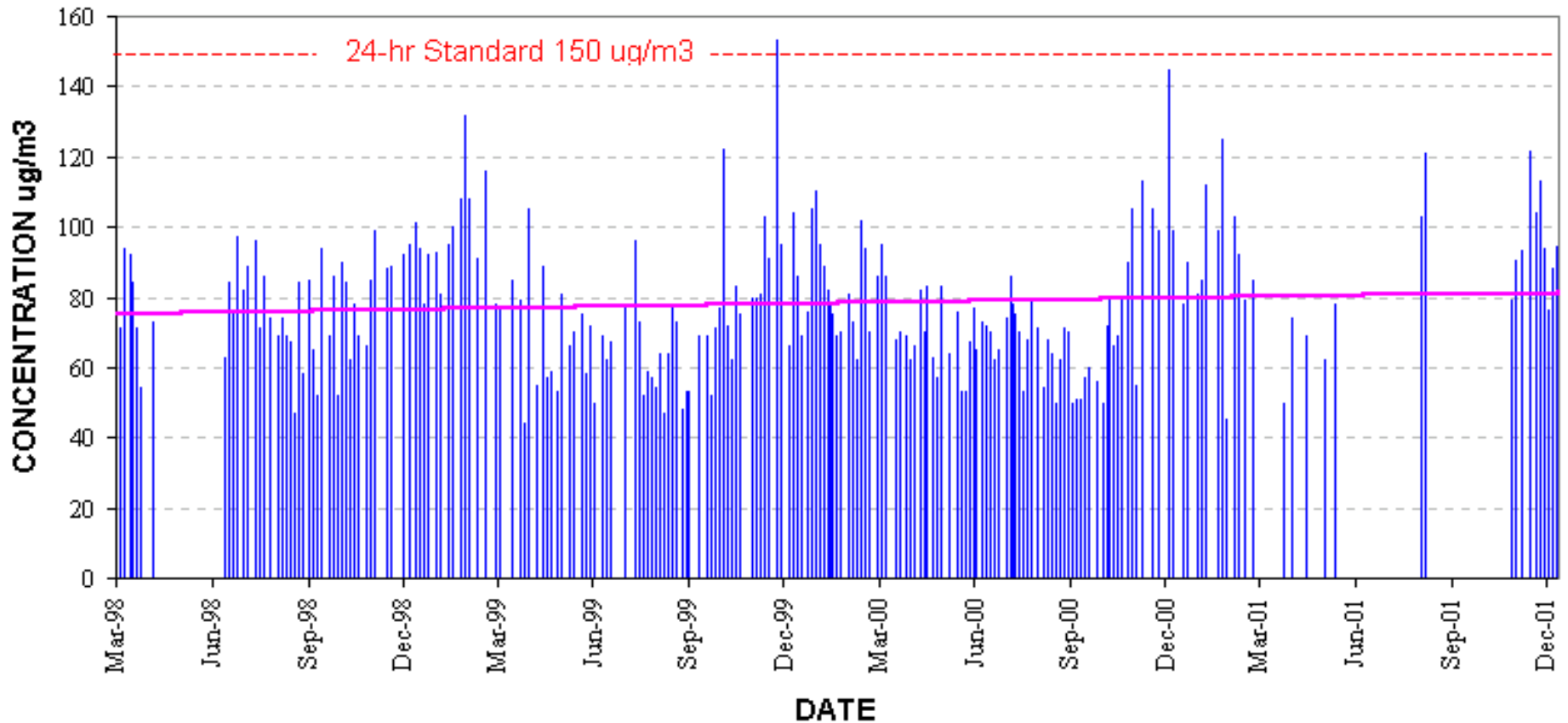
Carbon Monoxide Concentration Monthly Mean and Maximum of 1 hour averages at Colombo Fort (June 2003 - December 2006)



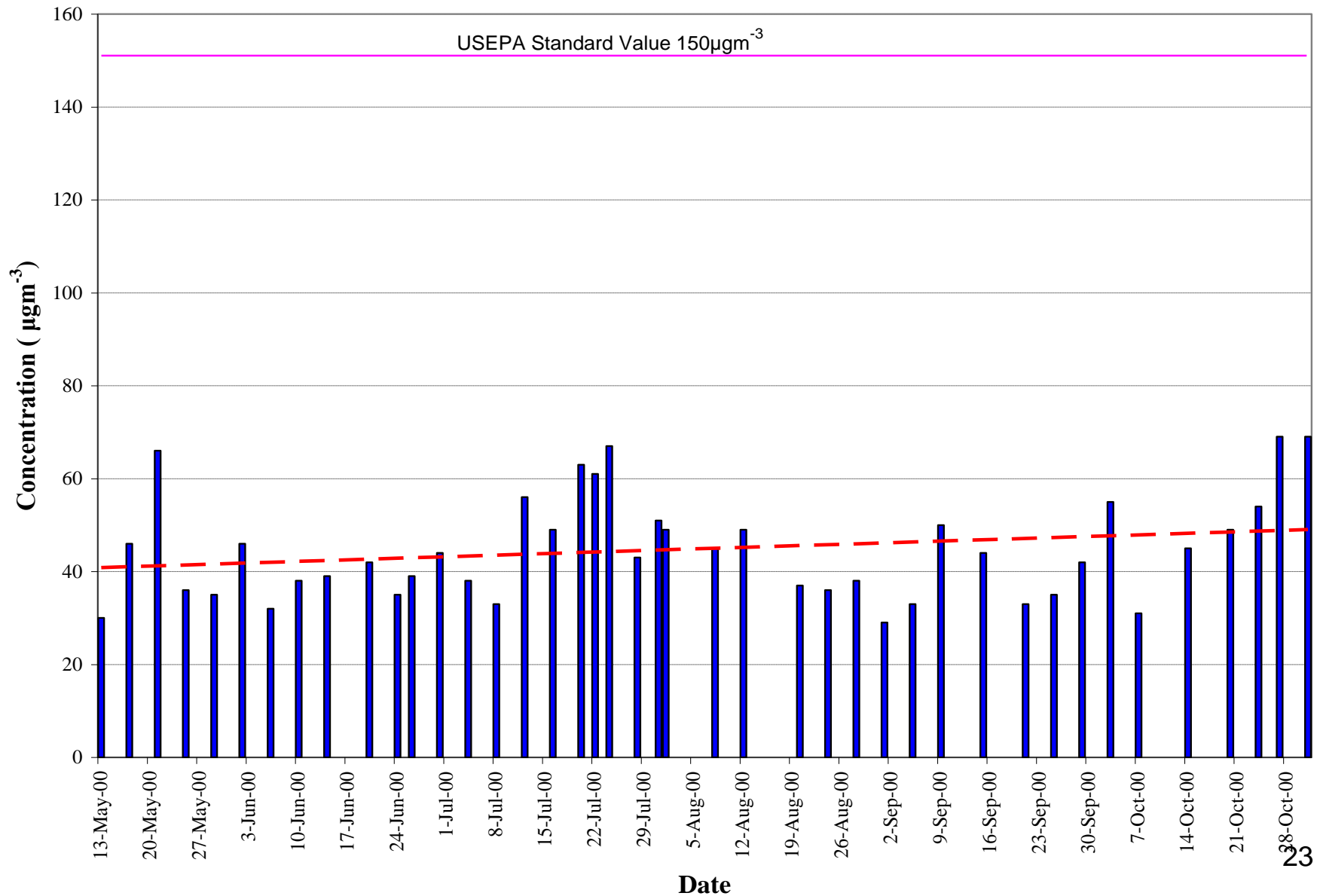
National Ambient Air Quality Standard for 24 hour average = 26 ppm



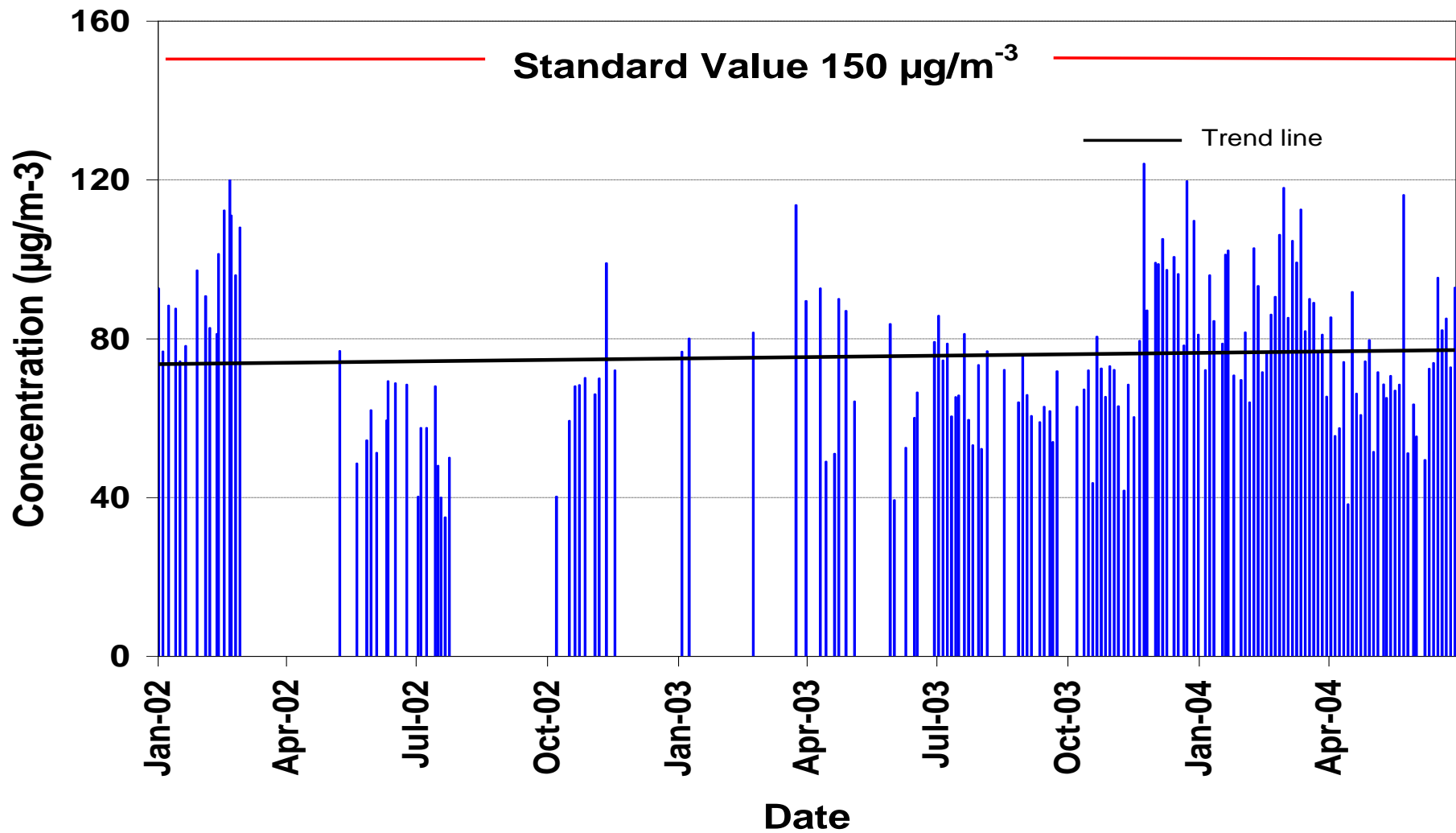
Variation of 24 hour averages of PM₁₀ concentrations at Colombo Fort Air Quality monitoring station (From Jan 1997 to December 2001)



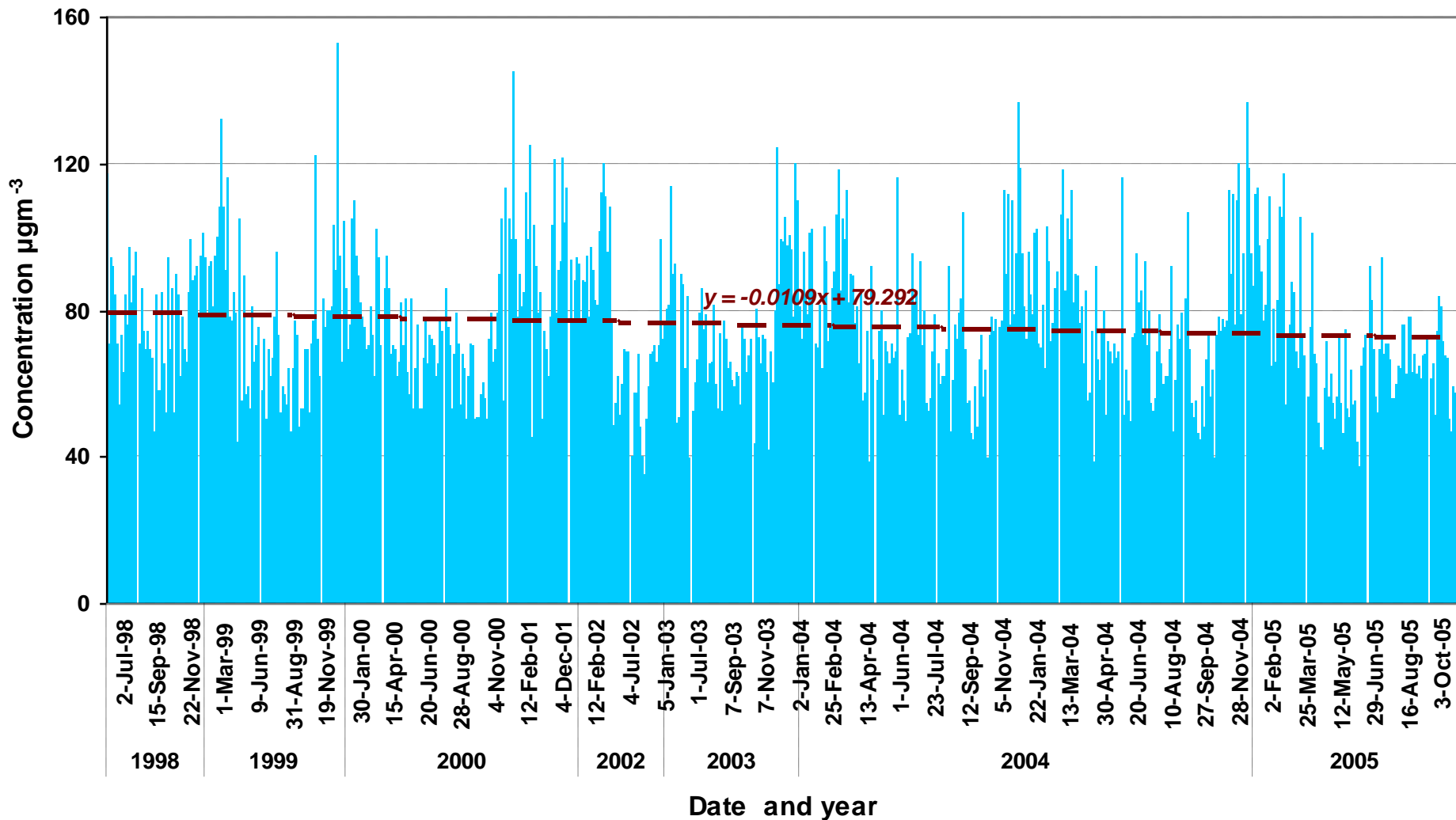
Variation of 24 hour averages of PM₁₀ concentrations at Colombo Meteorological Department Air Quality monitoring station (From Jan 1997 to December 2000)



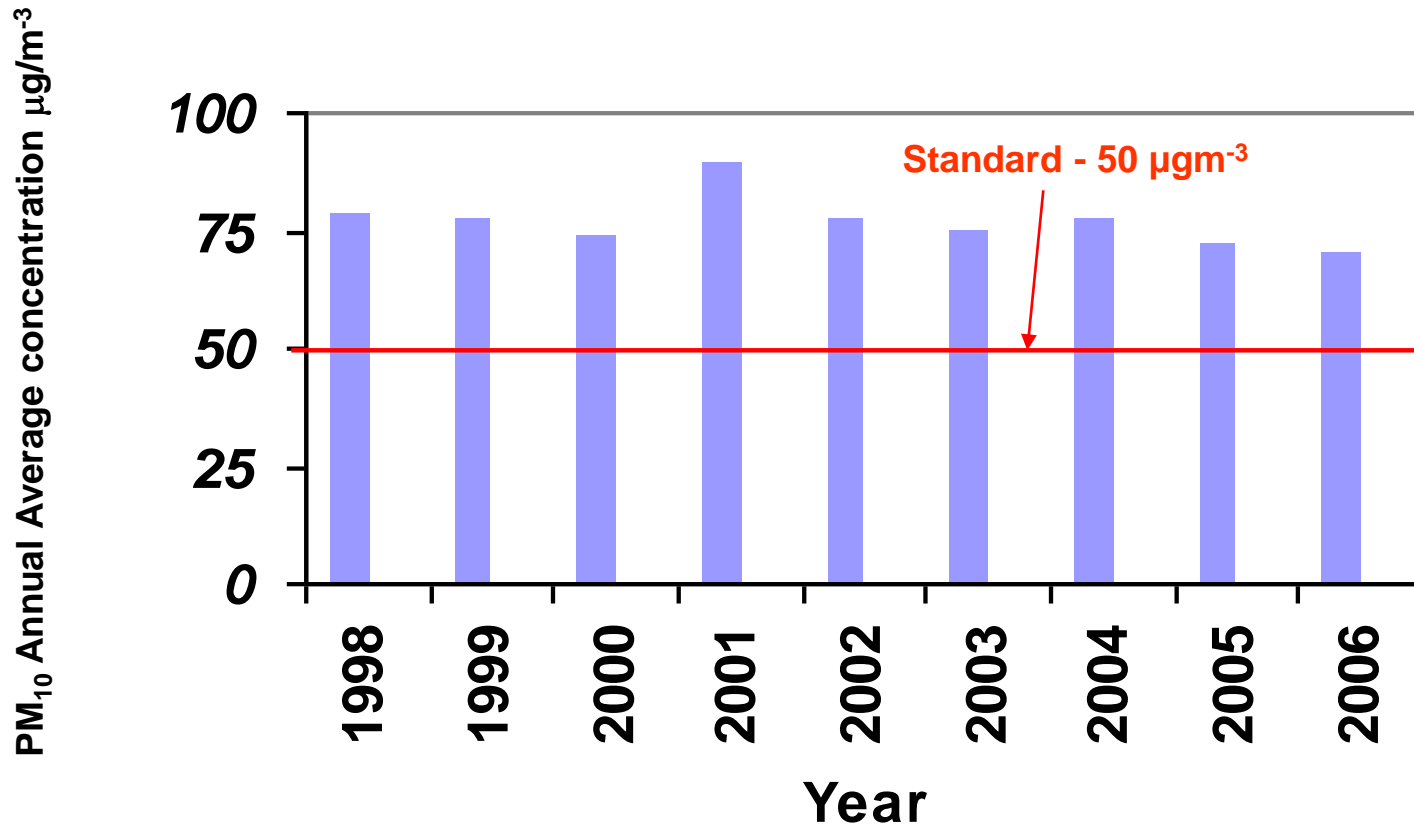
Variation of monthly one hour averages of PM₁₀ concentrations at Colombo Fort Air Quality monitoring station (From Jan 2002 to June 2004)



Variation of PM-10 concentrations (24 hour average) at Colombo Fort monitoring site
(from 1998 to 2005)



Annual averages of PM-10 at Colombo Fort Monitoring site (1998-2006)





Increasing trends of NO_2 , SO_2 & PM_{10}

- ❖ **Increasing amount of air pollutants with increasing number of vehicles and the capacity of thermal power generation utilizing fossil fuels were the major reasons for these increasing trends.**

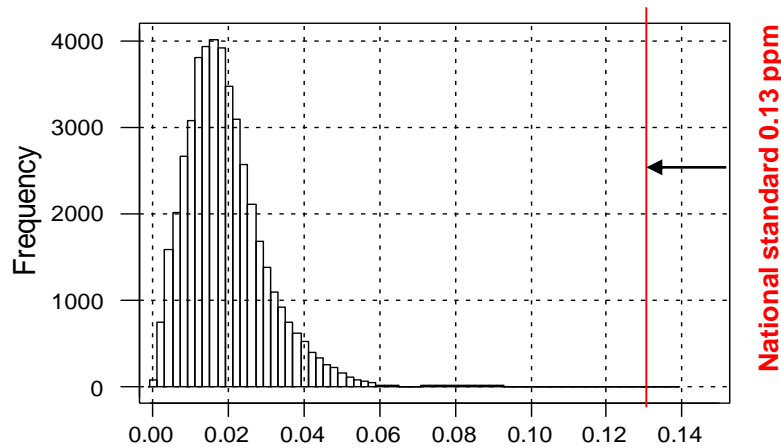


Increasing number of brand new passenger transport vehicles instead of re-conditioned vehicles the major reasons for these slight increasing trends

Decreasing trend of CO

- ❖ **Improvements of internal combustion engines to reduce emission, gradually decreasing of petrol driven vehicles in the vicinity of monitoring station are the major reasons and another possible reason was reaching more ultraviolet radiation into the lower atmosphere stimulating of producing hydroxyl free radicals for decline of carbon monoxide**

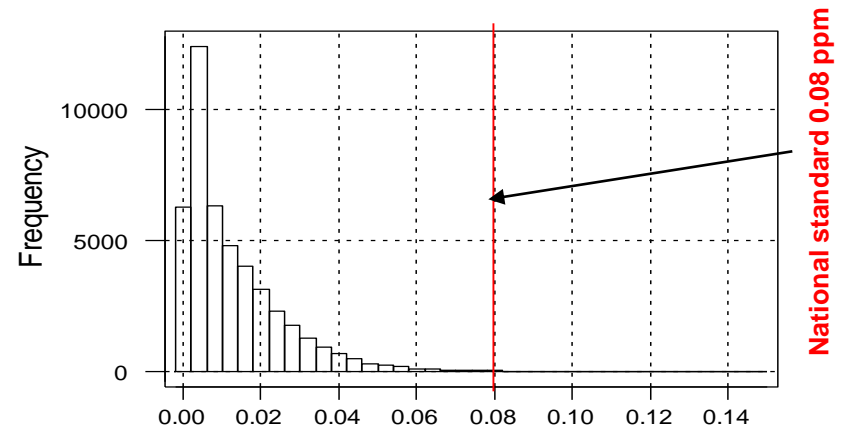
Comparisons of the variations of air quality monitoring data between Colombo Fort and Meteorological department sites



National standard 0.13 ppm

NO₂ Concentration (One hour average) in ppm

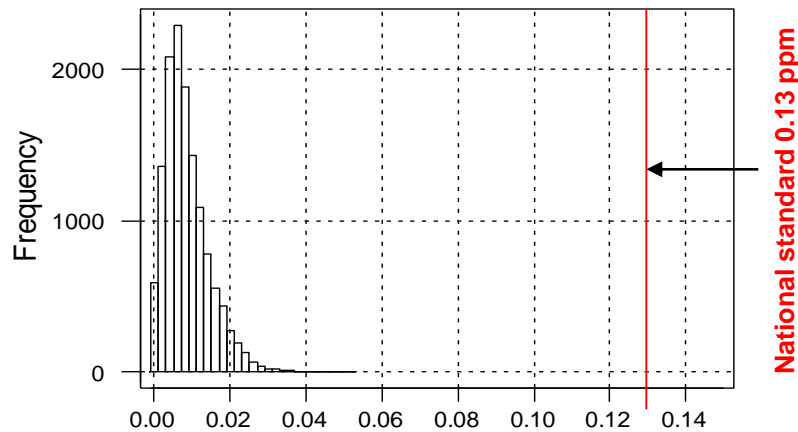
Frequency distribution of NO₂ one hour average concentrations at Colombo Fort (1997-2004)



National standard 0.08 ppm

SO₂ Concentration (One hour average) in ppm

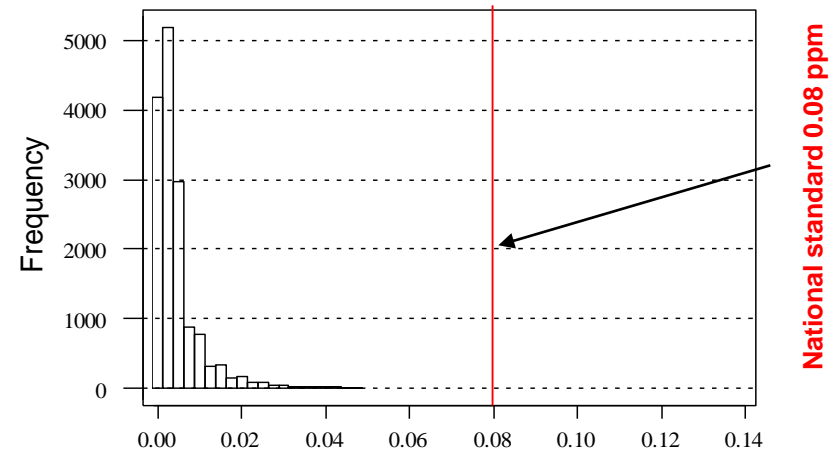
Frequency distribution of SO₂ one hour average concentrations at Colombo Fort (1997-2004)



National standard 0.13 ppm

NO₂ Concentration (One hour average) in ppm

Frequency distribution of NO₂ one hour average concentrations at Meteorological department (1997-2000)

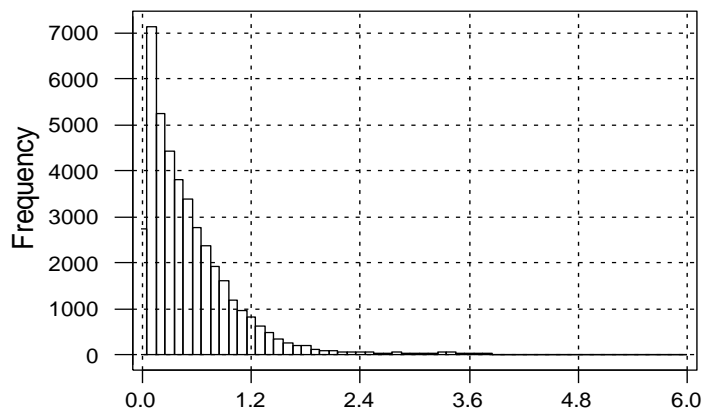


National standard 0.08 ppm

SO₂ Concentration (One hour average) in ppm

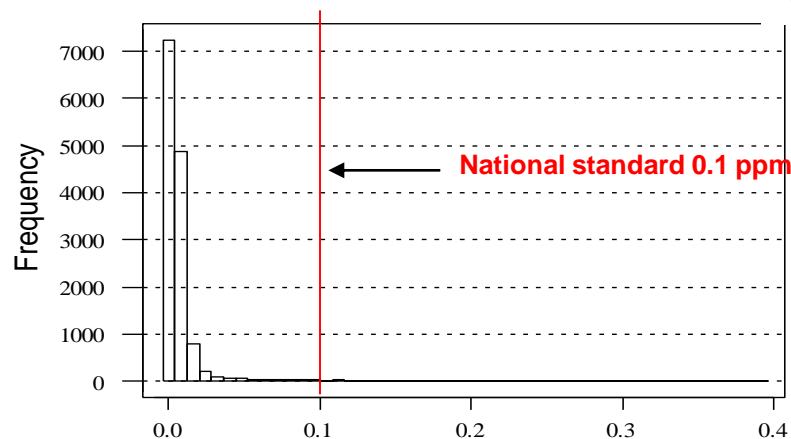
Frequency distribution of SO₂ one hour average concentrations at Meteorological department (1997-2000)

Comparisons of the variations of air quality monitoring data between Colombo Fort and Meteorological department sites Cont.....



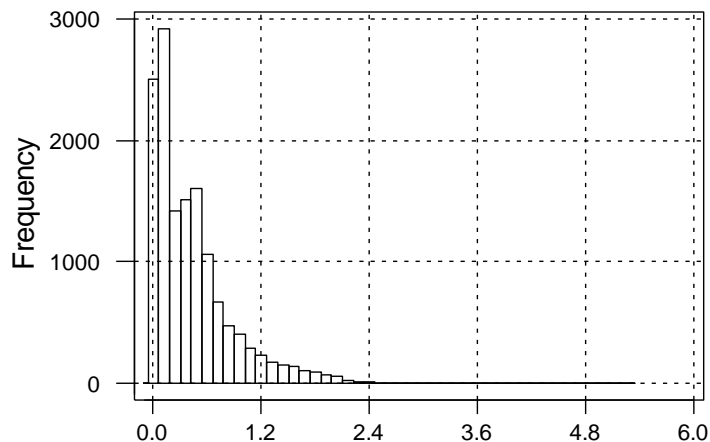
CO Concentration (One hour average) in ppm

Frequency distribution of CO one hour average concentrations at Colombo Fort (1997-2004)



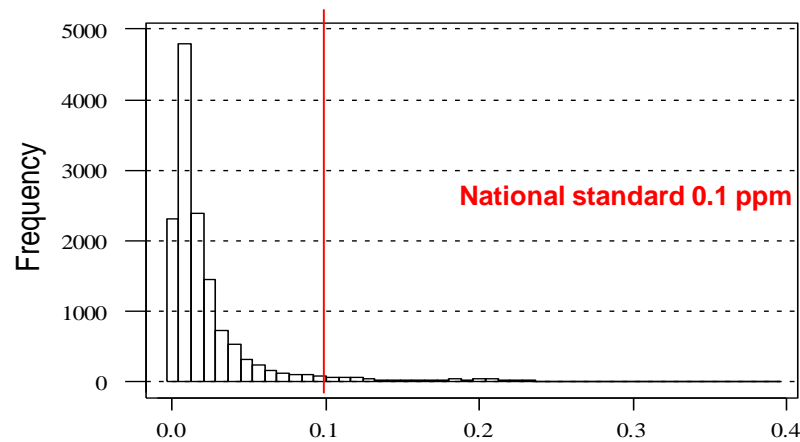
O₃ Concentration (One hour average) in ppm

Frequency distribution of O₃ one hour average concentrations at Colombo Fort (1997-2004)



CO Concentration (One hour average) in ppm

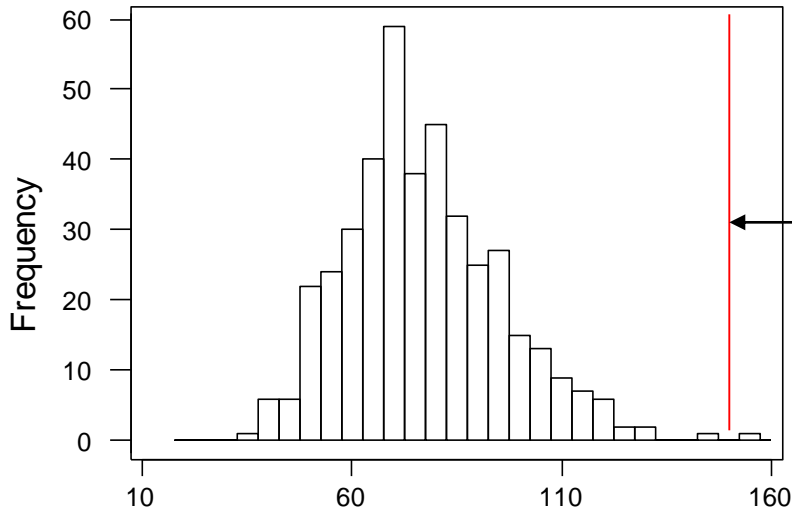
Frequency distribution of CO one hour average concentrations at Meteorological department (1997-2000)



O₃ Concentration (One hour average) in ppm

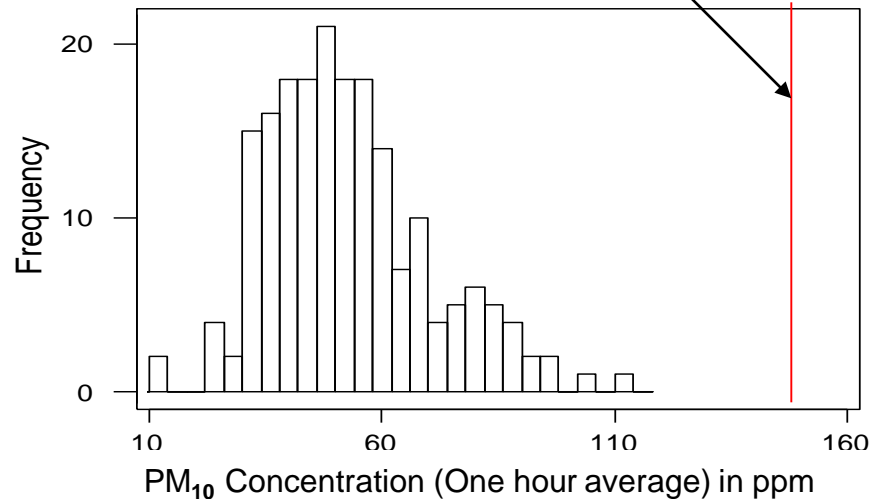
Frequency distribution of O₃ one hour average concentrations at Meteorological department (1997-2000)

Comparisons of the variations of air quality monitoring data between Colombo Fort and Meteorological department sites Cont.....



PM₁₀ Concentration (One hour average) in ppm

Frequency distribution of PM₁₀ 24 hour average concentrations at Colombo Fort (1997-2004)

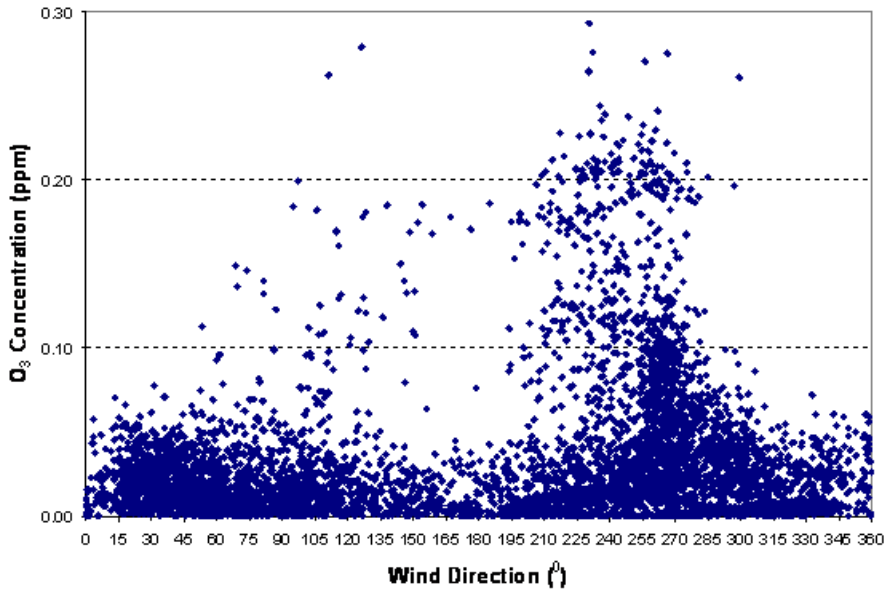
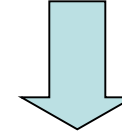


Frequency distribution of PM₁₀ 24 hour average concentrations at Meteorological department (1997-2000)

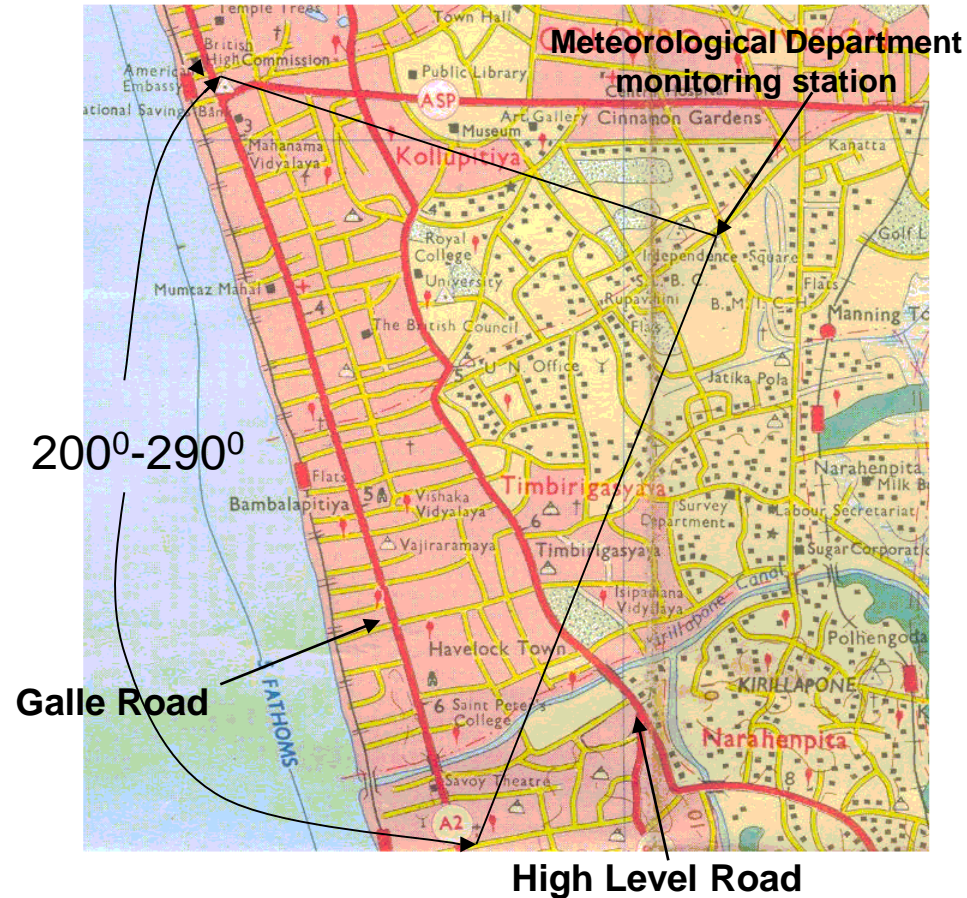




The area between 2000-2900 from Metec Department site.
(High ozone concentration recorded when wind came from this area).

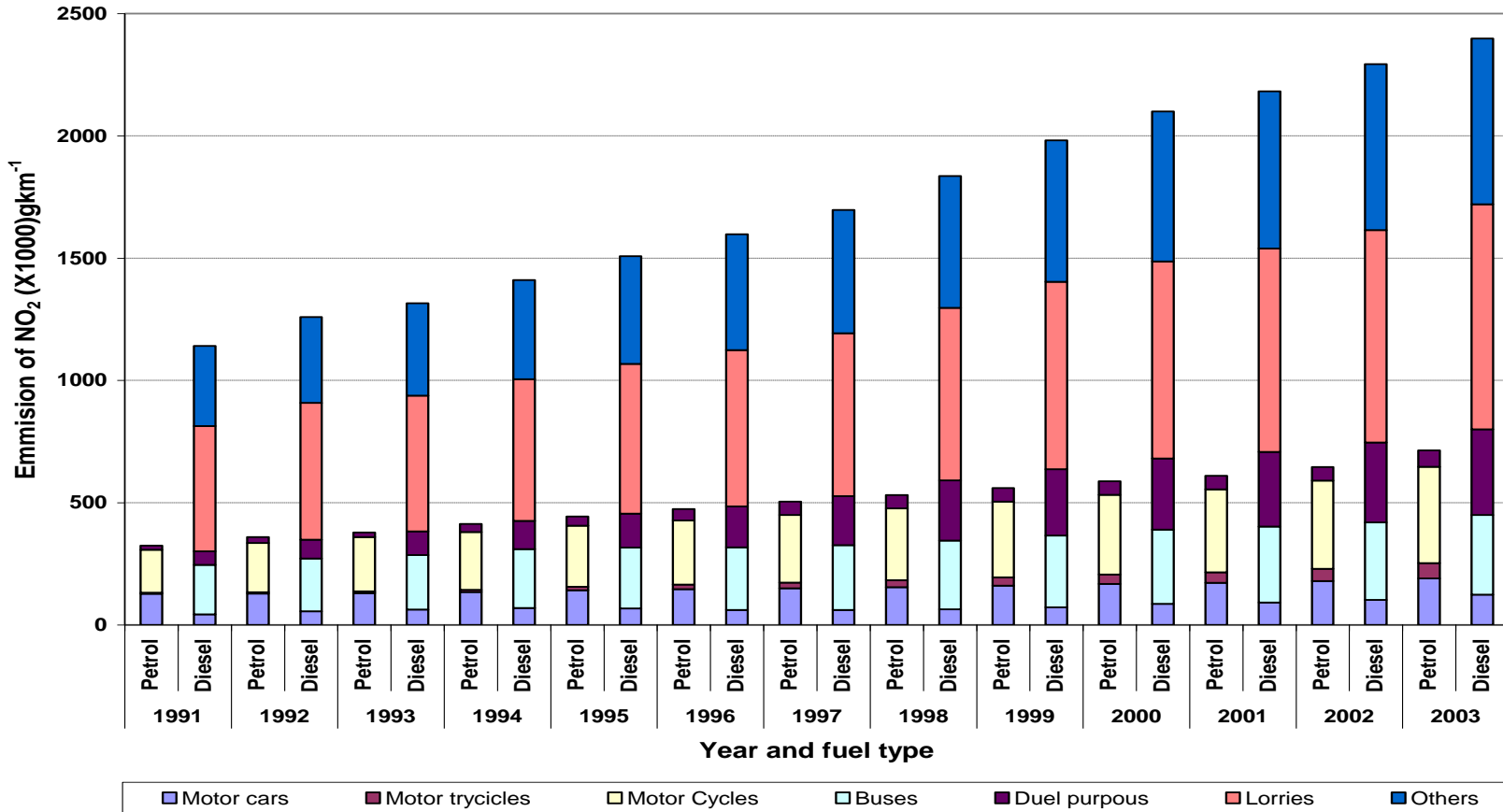


Variation of O₃ concentrations with wind direction
At Meteorological Department site





NO₂ emission from vehicles in Colombo Metropolitan Area (g/km)



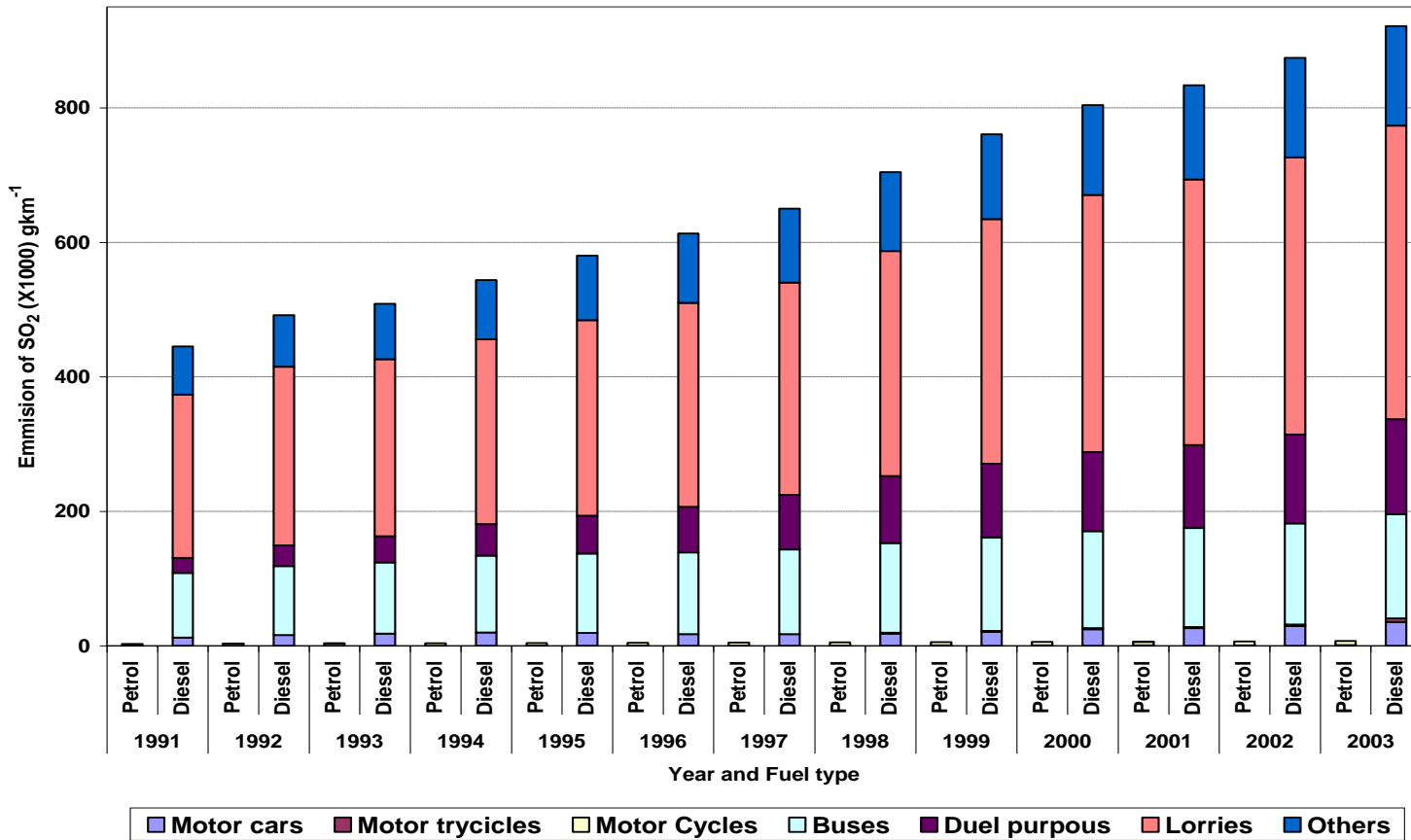
NO₂ emission of diesel three-wheelers are not included because

❖ **Difficulty to find NO₂ emission factor of diesel three-wheelers**

❖ **The number of diesel three-wheelers are very few compared to other vehicle groups**

60% of total number of vehicles registered in Sri Lanka are assumed to be in Colombo Metropolitan Area based on the study done by transport studies and planning center under CUTP in 1996

SO₂ emission from vehicles in Colombo Metropolitan Area (g/km)

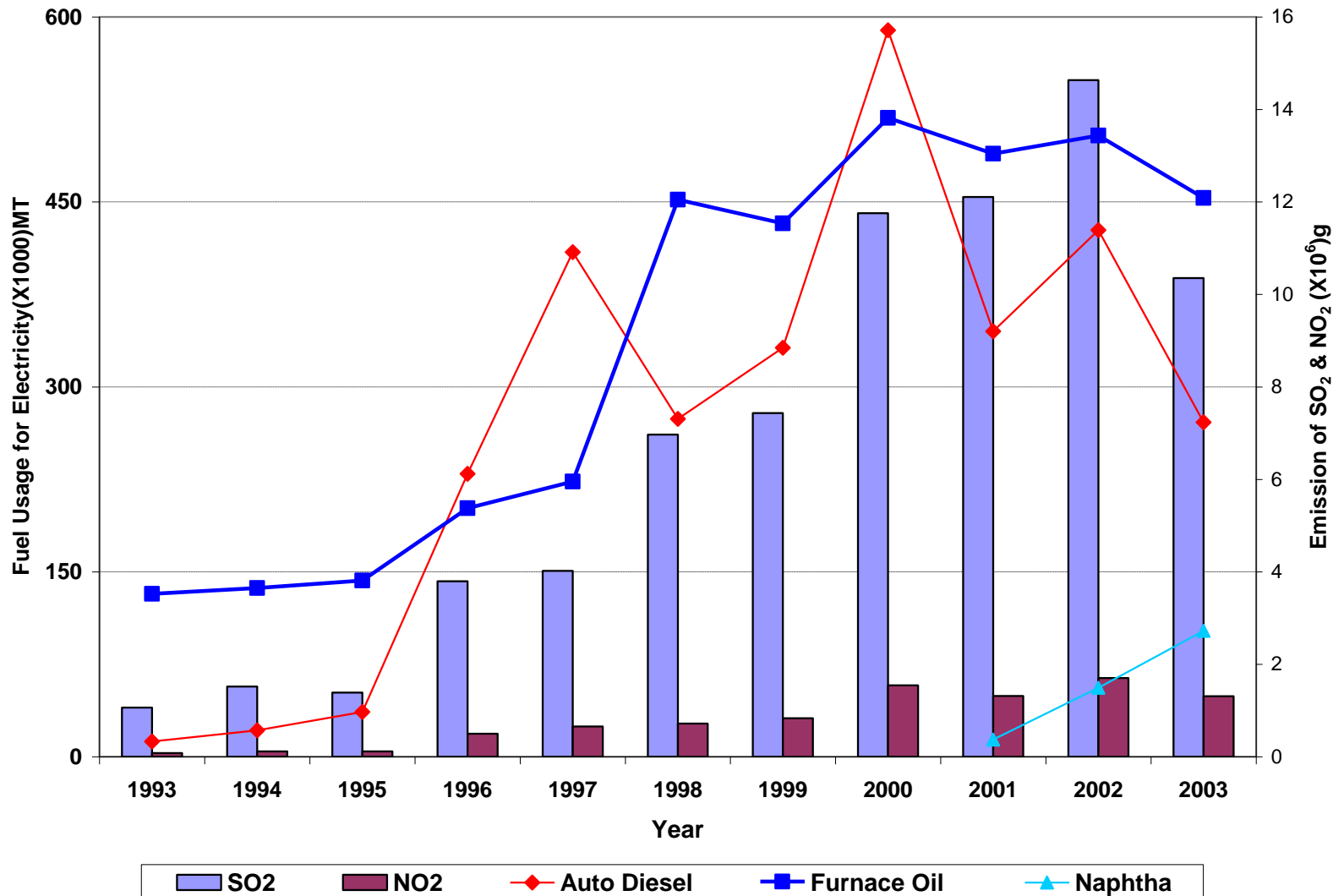


SO₂ emission of diesel three-wheelers are not included because

- ❖ **Difficulty to find SO₂ emission factor of diesel three-wheelers**
- ❖ **The number of diesel three-wheelers are very few compared to other vehicle groups**

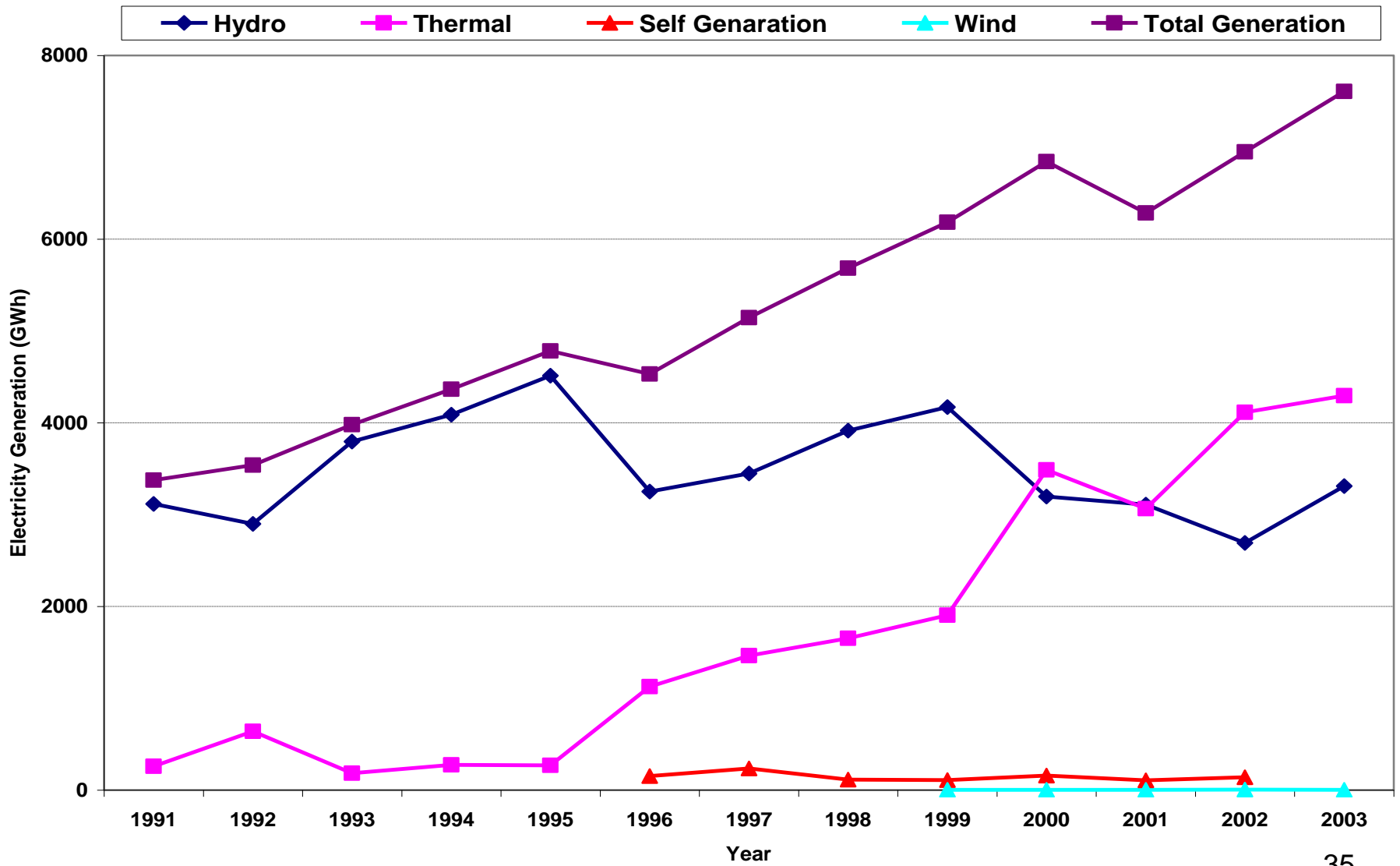
60% of total number of vehicles registered in Sri Lanka are assumed to be in Colombo Metropolitan Area based on the study done by transport studies and planning center under CUTP in 1996

Fuel consumption and amounts of NO₂ and SO₂ emissions relevant to the power sector in Sri-Lanka

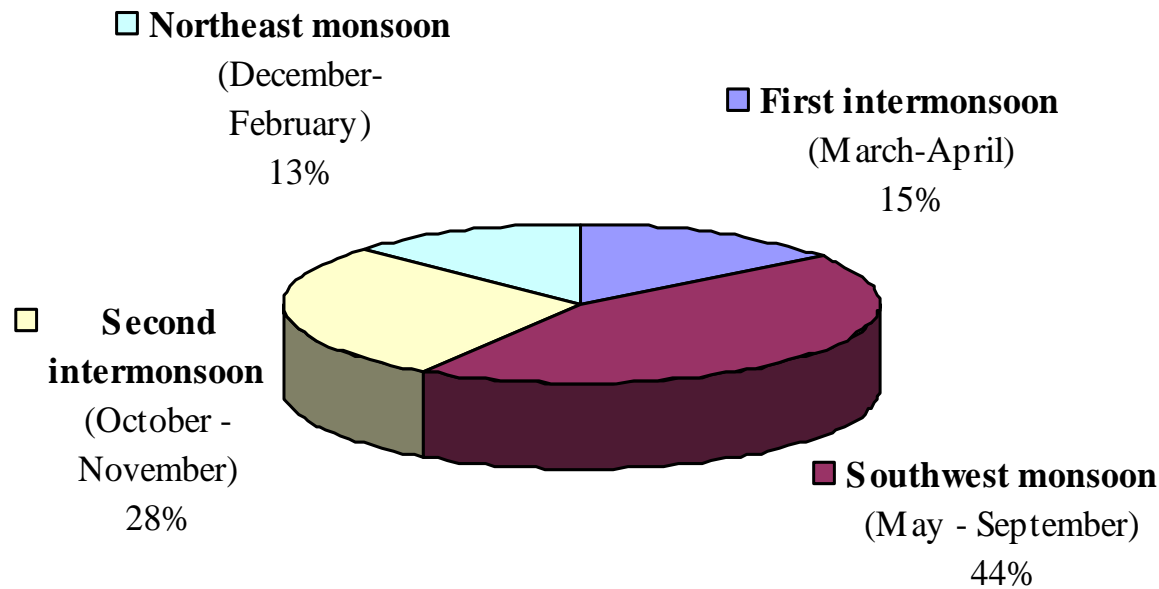




Electricity generation of Sri-Lanka



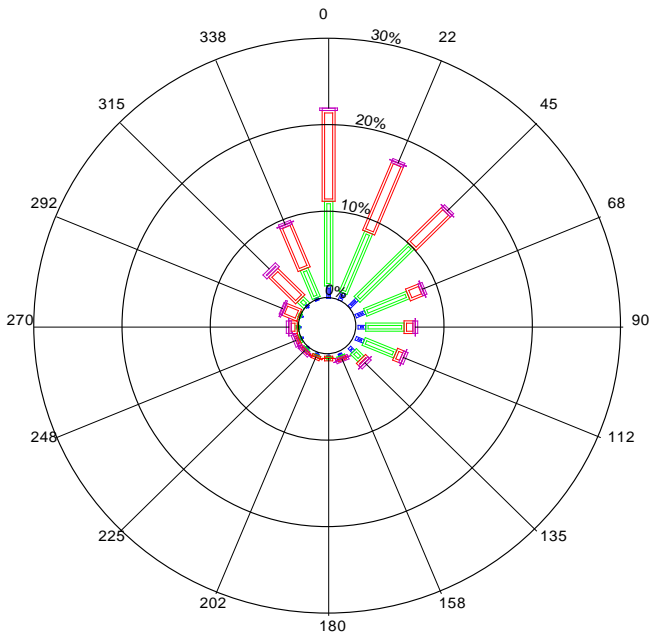
Variation of rainfall in four seasons during the year in Colombo



Rainfall data- Report on Climate by M.B.G.de Silva based on rainfall data from 1961-1990
in Arjun's Atlas of Sri Lanka

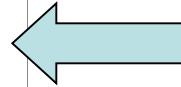


Wind pattern of four monsoonal seasons during the year at Colombo Fort monitoring



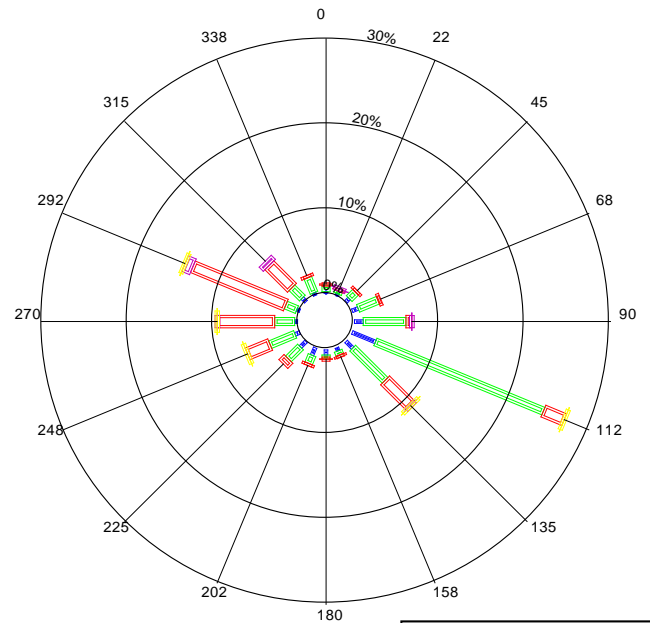
Magnitude(ms^{-1})

Rainfall 13%



**North-East monsoon
(December – February)**

**First inter-monsoon
(March – April)**

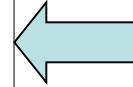
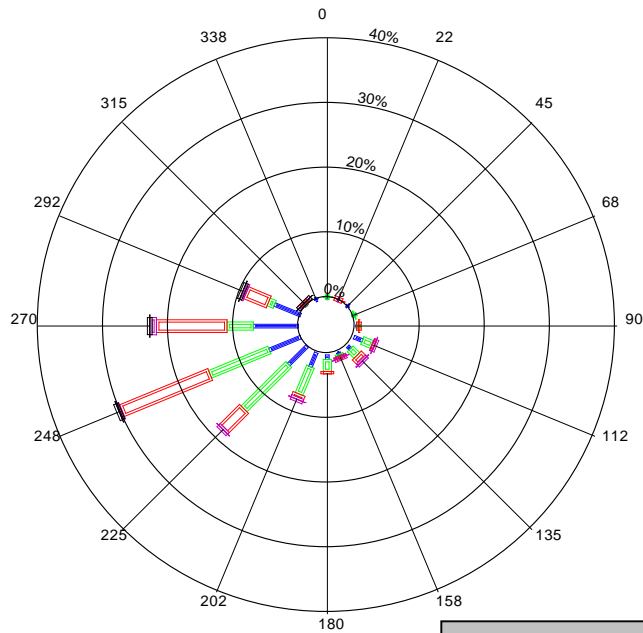


Magnitude(ms^{-1})

Rainfall 15%



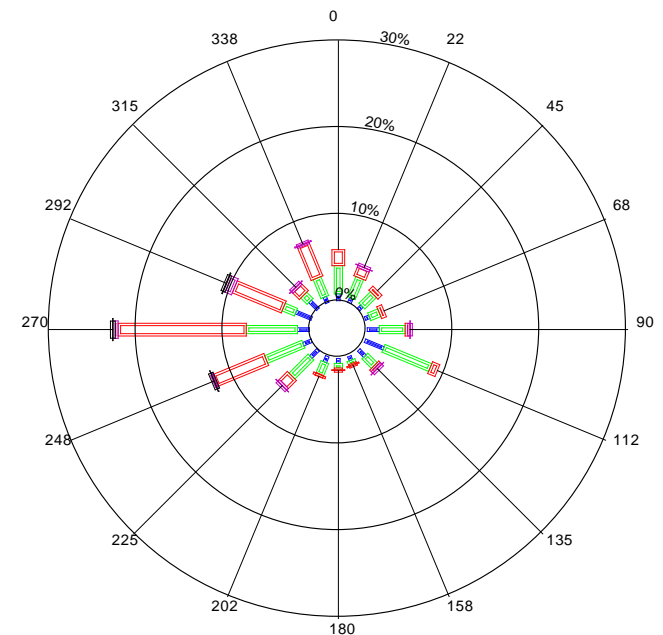
Wind pattern of four monsoonal seasons during the year at Colombo Fort monitoring



**South-west monsoon
(May to September)**

Magnitude(ms⁻¹)

Rainfall 44%



**Second inter-monsoon
(October to November)**

Magnitude(ms⁻¹)

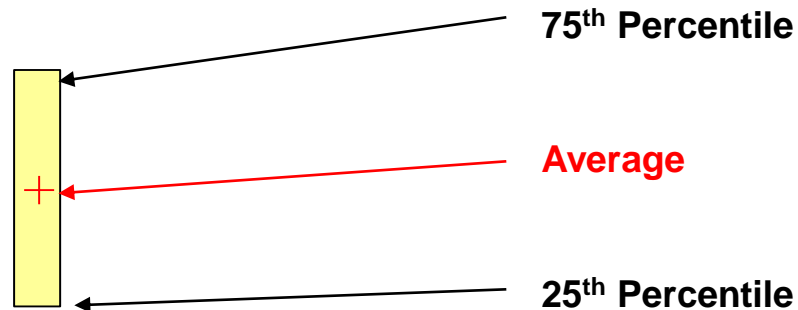
Rainfall 28%

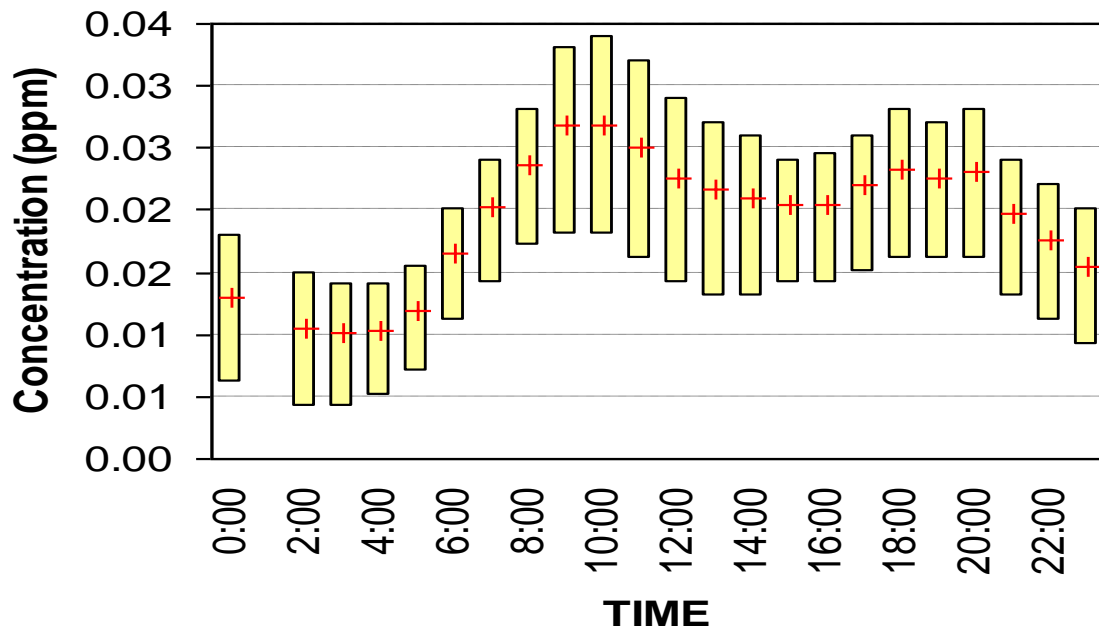




Variation of air pollutant concentrations with time and date

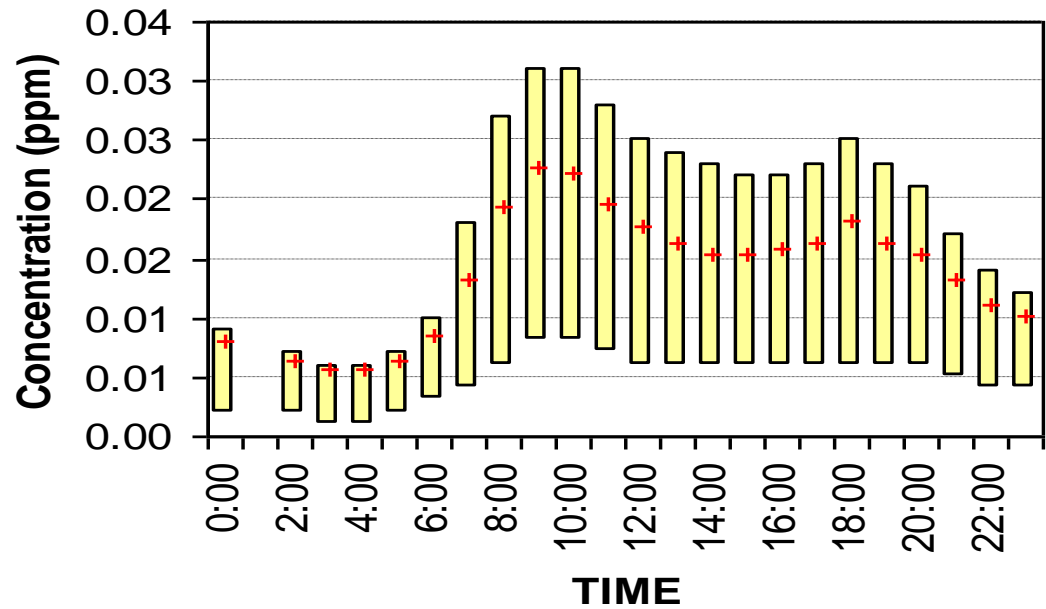
- ❖ The statistical parameters calculated with respect to the time and date were presented in graphical form to study the variation patterns during the day and the week.
- ❖ The statistical parameters of air pollutants are represented in these graphs in following format.

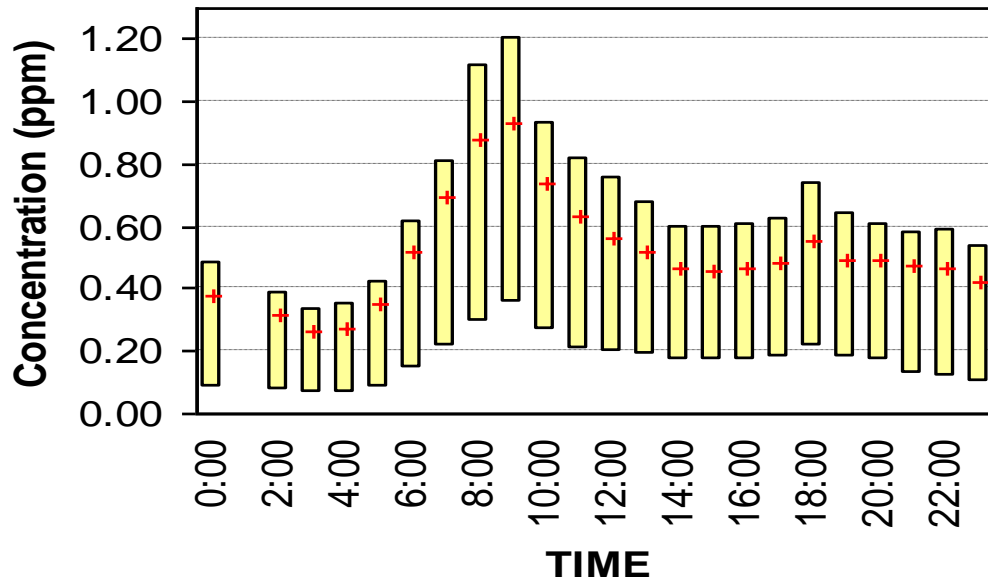




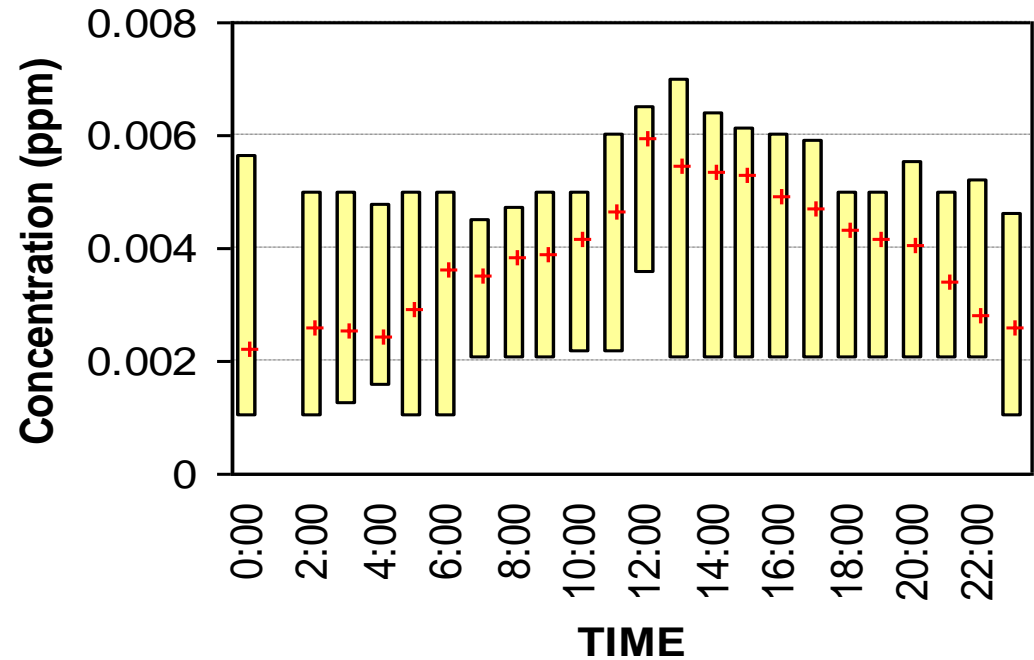
Variation of one hour averages of NO_2 concentrations with time at Colombo Fort monitoring station

Variation of one hour averages of SO_2 concentrations with time at Colombo Fort monitoring station

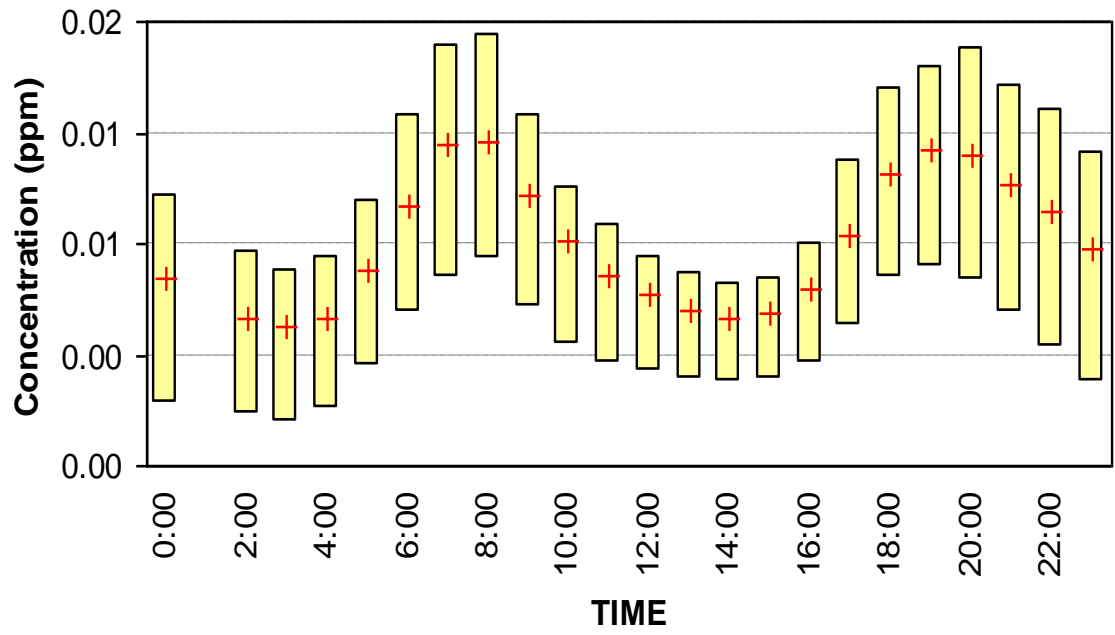




Variation of one hour averages of CO concentrations with time at Colombo Fort monitoring station

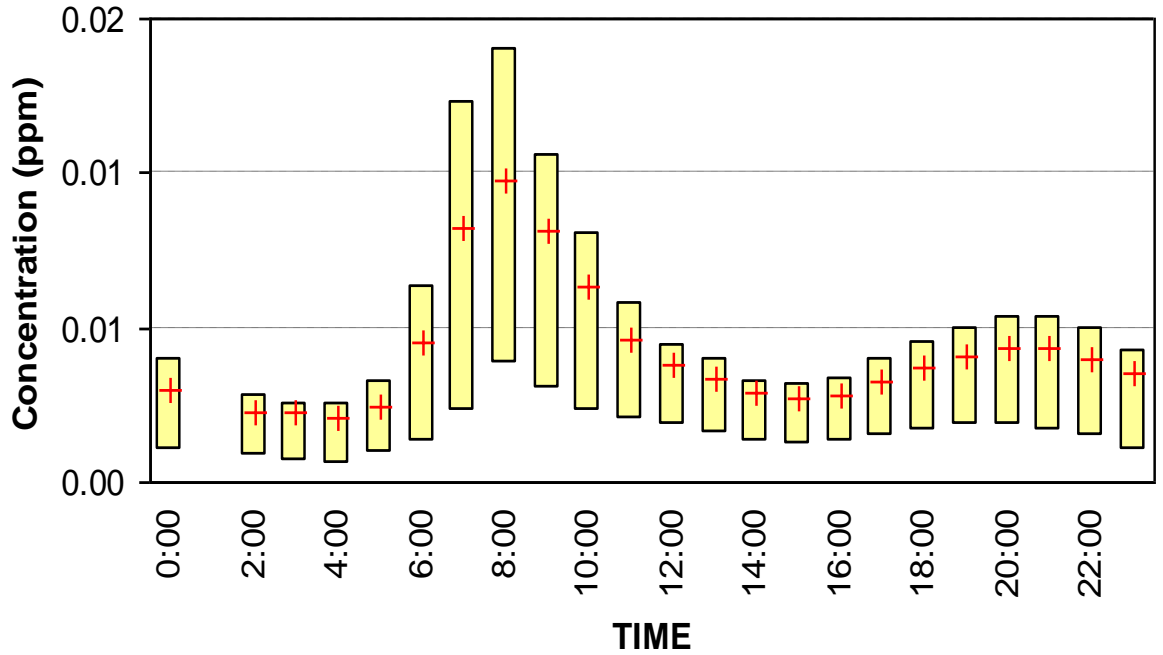


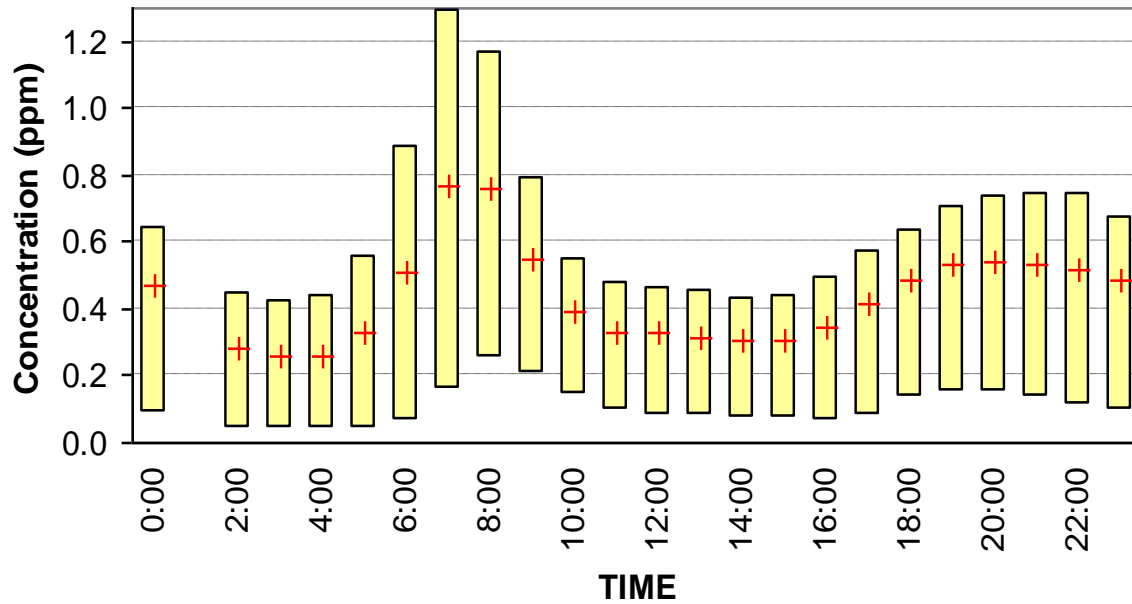
Variation of one hour averages of O₃ concentrations with time at Colombo Fort monitoring station



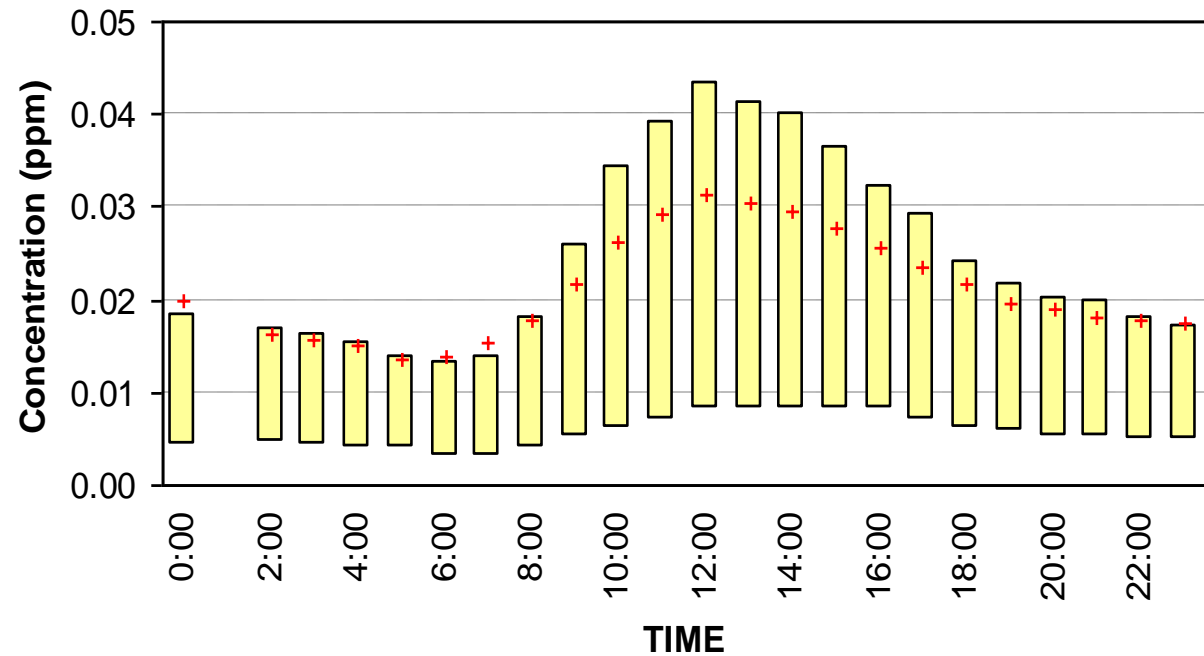
Variation of one hour averages of NO₂ concentrations with time at Colombo Meteorological Department monitoring station

Variation of one hour averages of SO₂ concentrations with time at Colombo Meteorological Department monitoring station



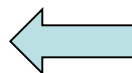
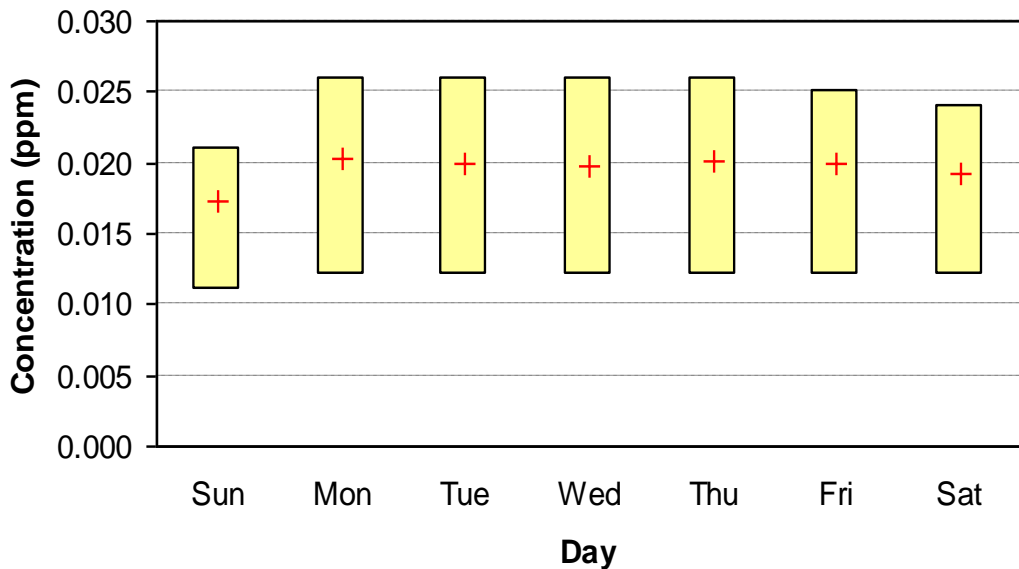


Variation of one hour averages of CO concentrations with time at Colombo Meteorological Department monitoring station



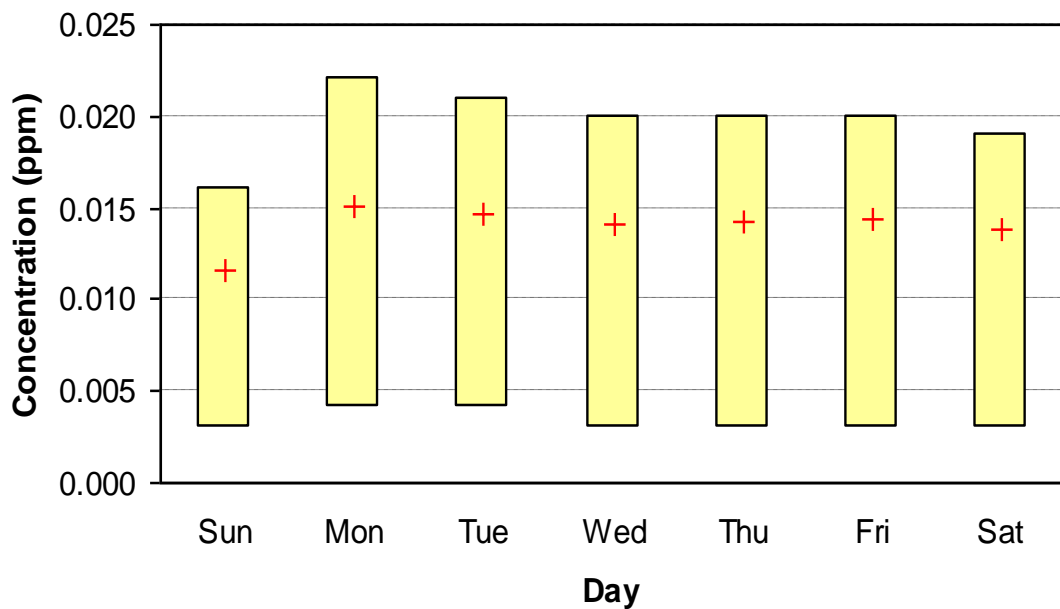
Variation of one hour averages of O₃ concentrations with time at Colombo Meteorological Department monitoring station

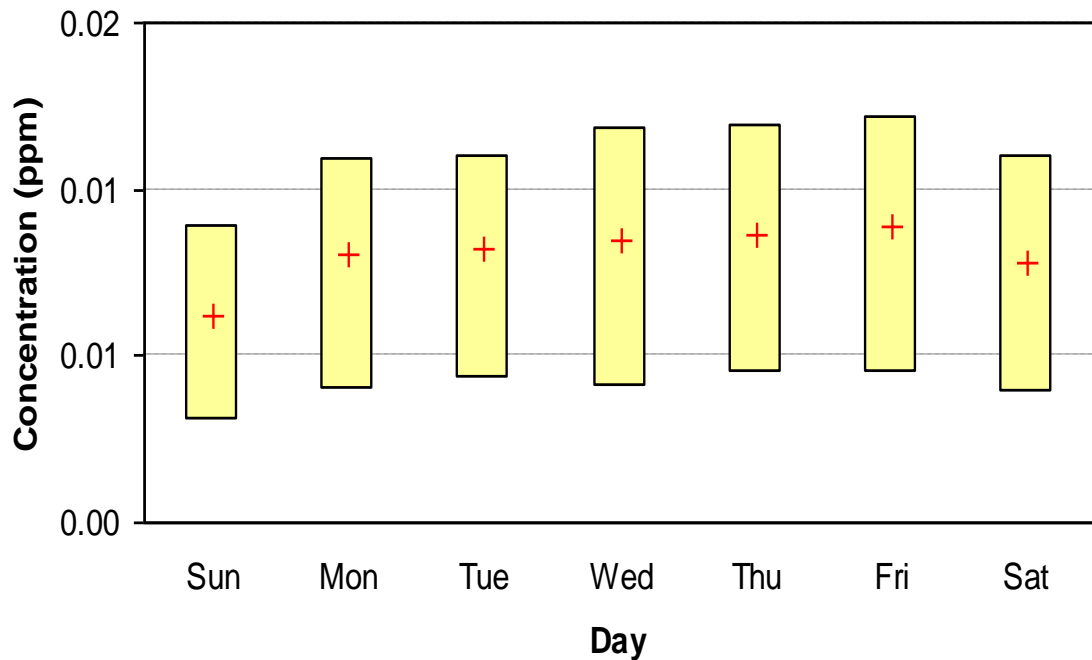
Variation of air pollutant concentrations with date



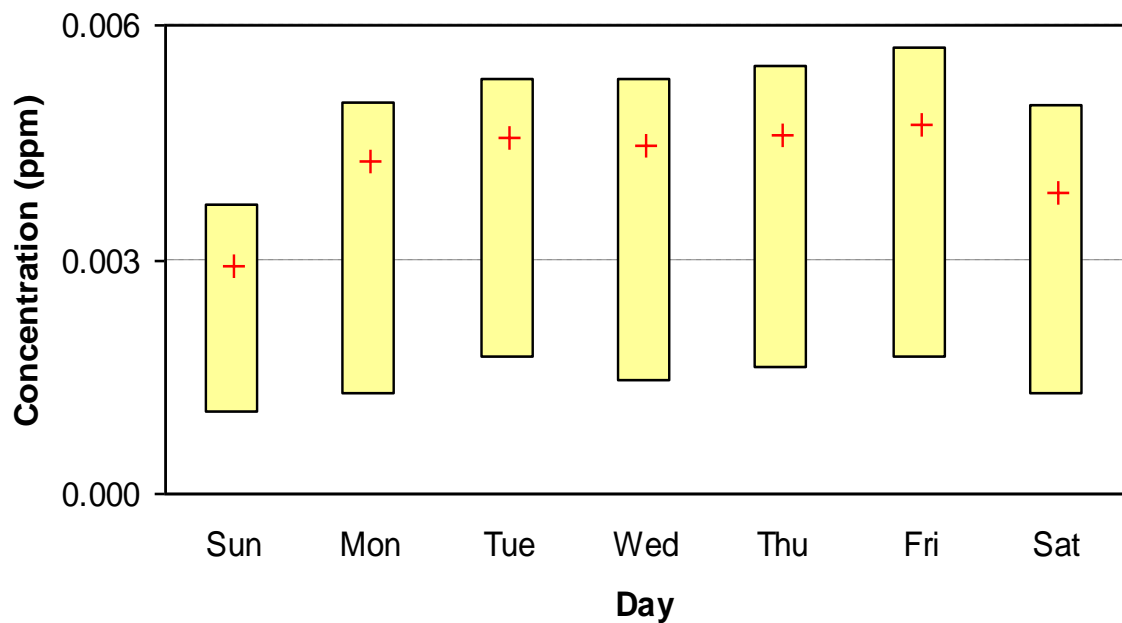
Variation of one hour averages of NO_2 concentrations with day at Colombo Fort monitoring station

Variation of one hour averages of SO_2 concentrations with day at Colombo Fort monitoring station

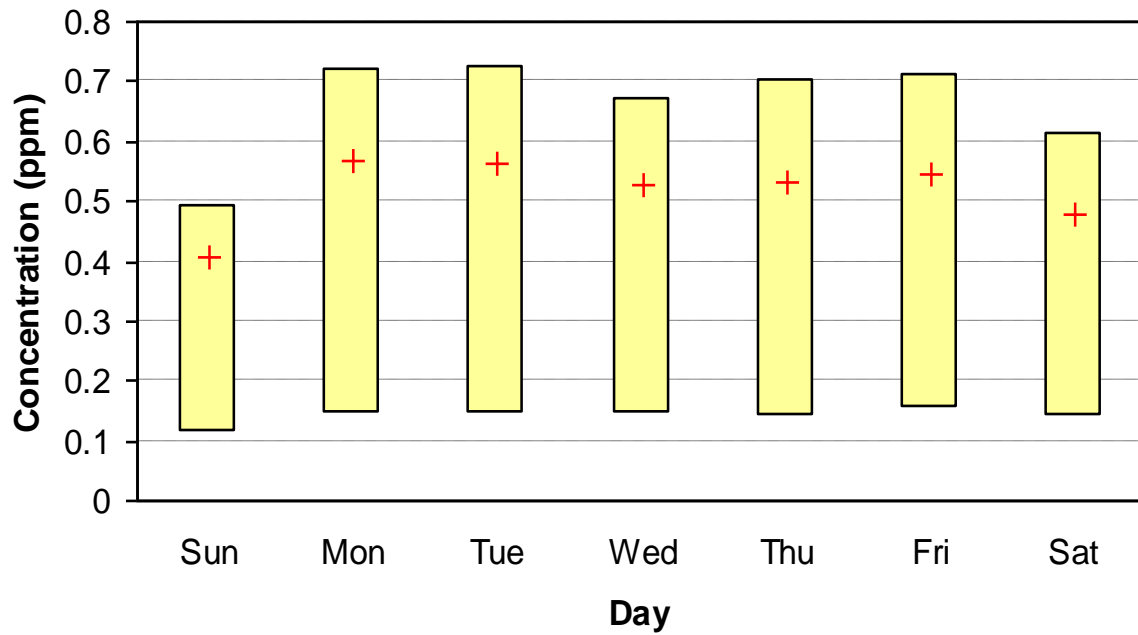




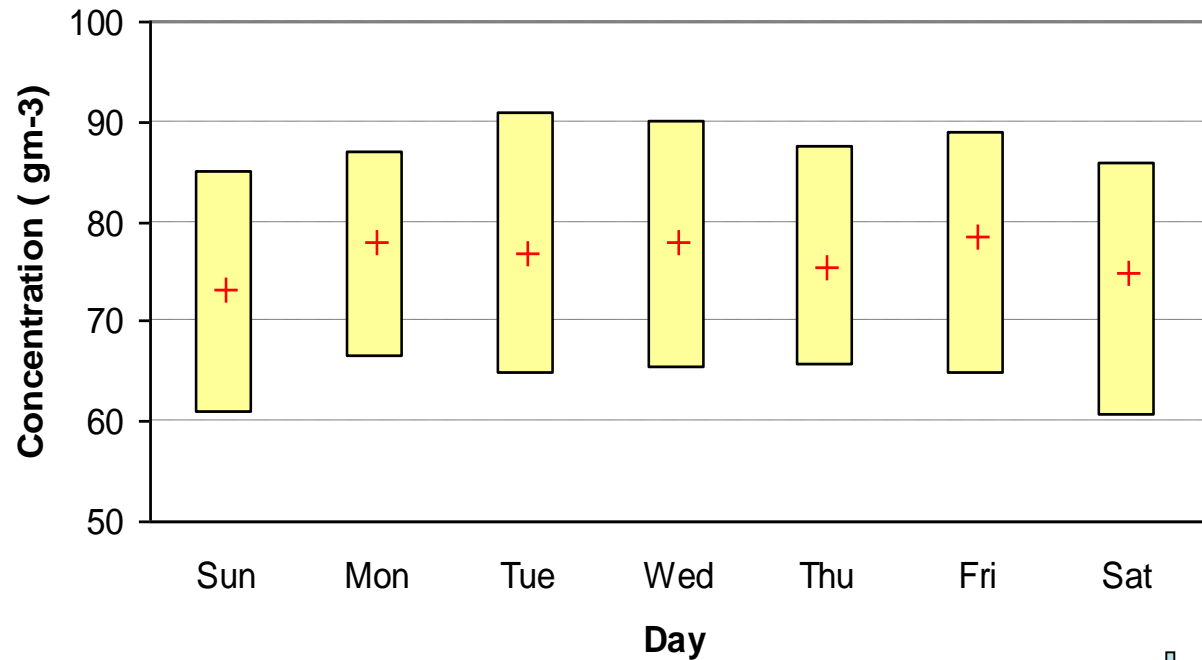
Variation of one hour averages of NO_2 concentrations with day at Colombo Meteorological Department monitoring station



Variation of one hour averages of SO_2 concentrations with day at Colombo Meteorological Department monitoring station



Variation of one hour averages of CO concentrations with day at Colombo Fort monitoring station



Variation of 24 hour averages of PM₁₀ concentrations with day at Colombo Fort monitoring station





CONCLUSIONS

Air pollution trends with respect to sulfur dioxide and nitrogen dioxide are slowly increasing while carbon monoxide is slowly decreasing.

Increasing amount of air pollutants with increasing number of vehicles and the capacity of thermal power generation utilizing fossil fuels were the major reasons for these increasing trends.

Improvements of internal combustion engines to reduce emission, gradually decreasing of petrol driven vehicles in the vicinity of monitoring station are the major reasons and another possible reason was reaching more ultraviolet radiation into the lower atmosphere stimulating of producing hydroxyl free radicals for decline of carbon monoxide

The trend with respect to PM_{10} is slowly increasing over the period from Jan 1998 to June 2003. However , reaseantly we observed slight decreasing of PM-10



CONCLUSIONS Cont.....

Emissions from increasing fleet of vehicles are the major contributor of air pollution in Colombo City.

The emissions from thermal power stations operating in and near the Colombo metropolitan area using relatively high sulfur fuel are added burden for air pollution in Colombo City.

Prevailing wind pattern and rainfall pattern with monsoons are the major factors for seasonal variation pattern of air pollutants concentrations.

PM10 concentration in Colombo city with presence of sulfur dioxide is the serious cause to concern.



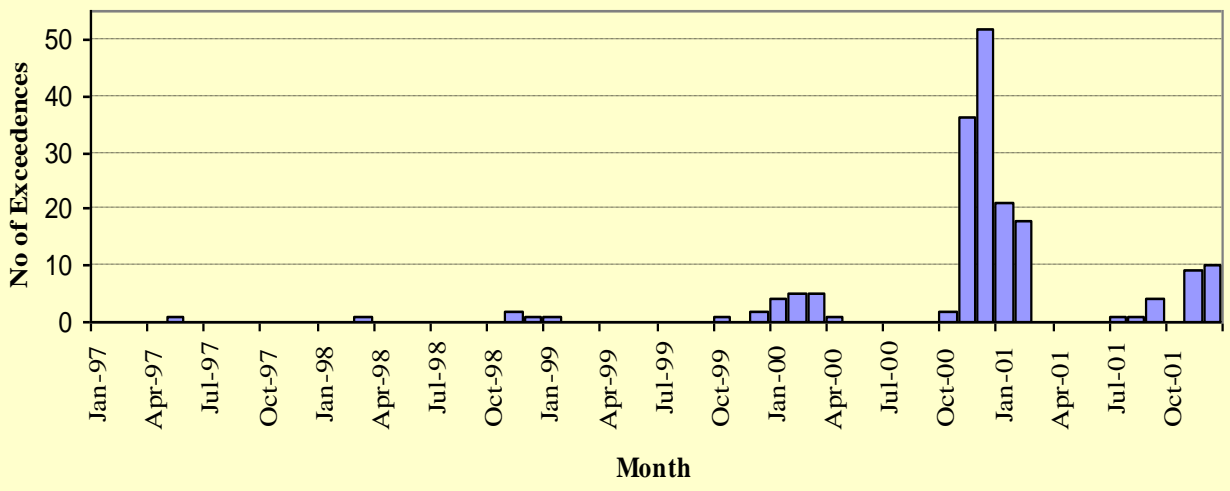


Thank you

References

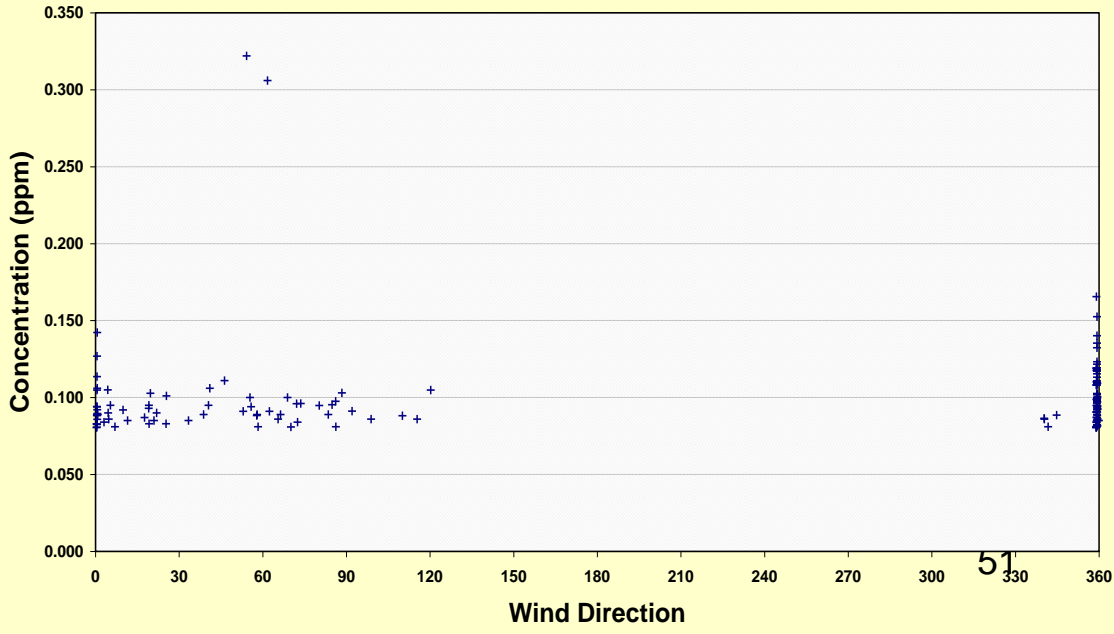
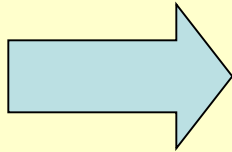
- 1 **Howard S.Peavy,Donald R. Rowe and George Tchobanoglous, (International Ed), *Environmental Engineering*, McGraw-Hill, Singapore(1985) p.1-8 & 418-463**
- 2 **Bernard J Nebel & Richard T Wright,(7th Ed),*Environmental Science The way the world works*, Prentice Hall, Upper saddle River, New Jersey.(p 524-549)**
- 3 **PGIS, University of Peradeniya, *Workshop on Acid Rain Monitoring & Air Quality Monitoring and Management Proceedings*,(2001).p1-5**
- 4 **Arudpragasam K.D. (Editor in chief), *Man And Environment, An introduction to Environmental Studies*, Central Environmental Authority , Colombo 10, (1999), p129-164**
- 5 **UEPA,APTI, *Air Pollution Control Orientation Course Self-Instructional Manual*, Air Pollution Training Institute(APTI),Environmental Research Center , NC 27711,USA (1992)**
- 6 **Lakdasa Wijethilake and Suhashini A.R.Karunaratne, *Air Quality Management Considerations for Developing countries*, World Bank Technical Paper Number 278,The World Bank, Washington D.C.(1995)**
- 7 **UNEP,Urbun air pollution,GEMS Environmental library NO-04,UNEP, Niroby, Kenya (1998)**
- 8 **World Health Organization, *Guidelines For Air Quality*,World Health Organization, Geneva (2000)**
- 9 **Jiry Hanzak, Jaroslav Pekarec, *Volatile Organic Compounds in the Atmosphere at the background level, Report on case study*, Czech hydro meteorological institute, Kosetice observatory, Czech Republic**

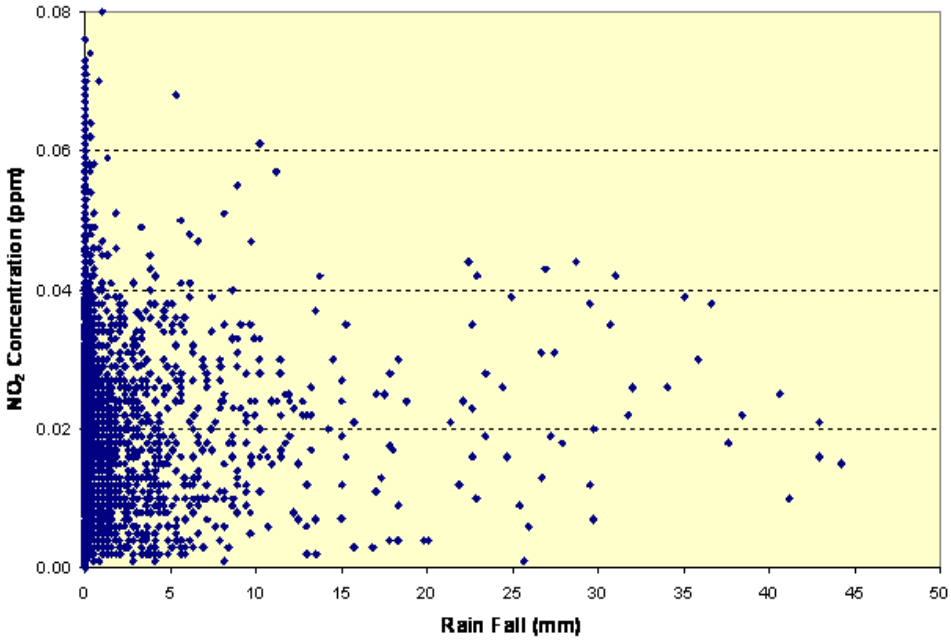
Exceedences of one hour averages SO₂ from national standard at Colombo Fort Monitoring site (1997-2001)



Number of exceedences of one hour average concentration of SO₂

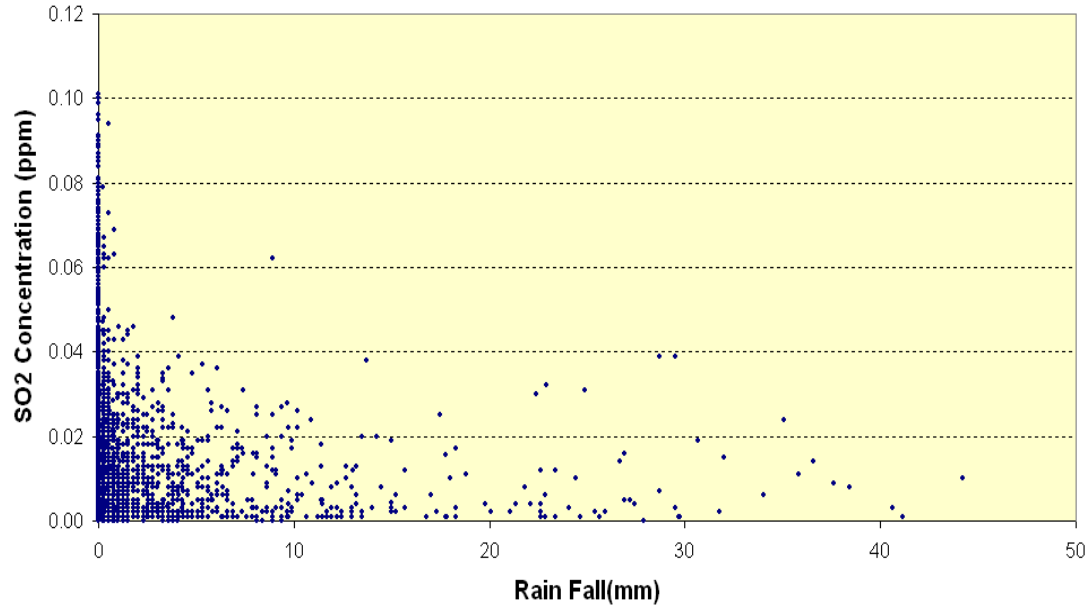
Variation of SO₂ exceedences with wind direction

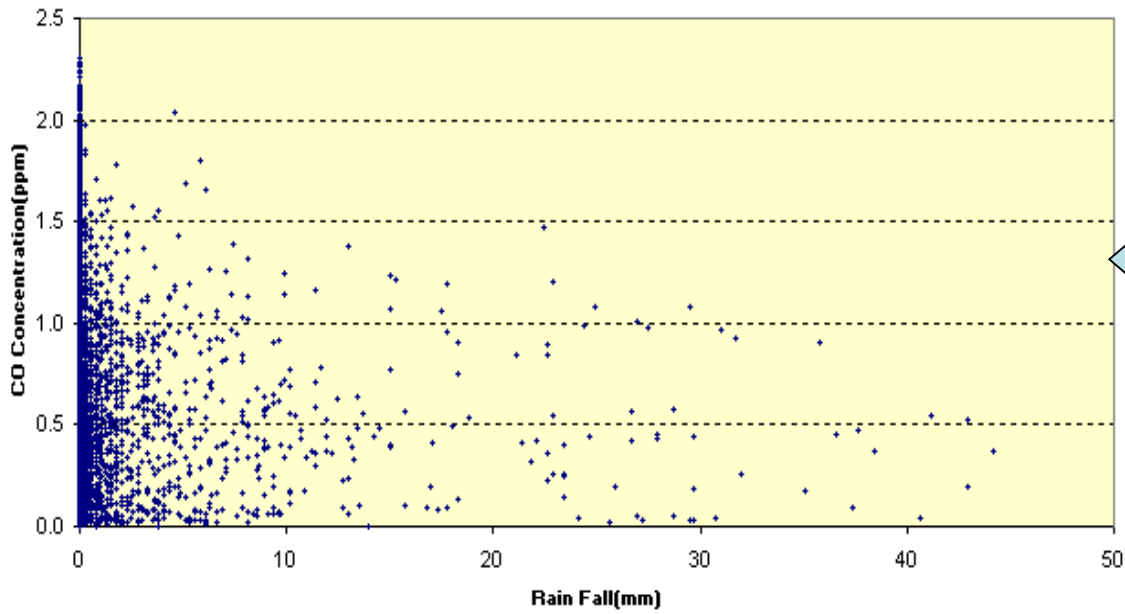




Variation of NO₂ concentrations with rain fall

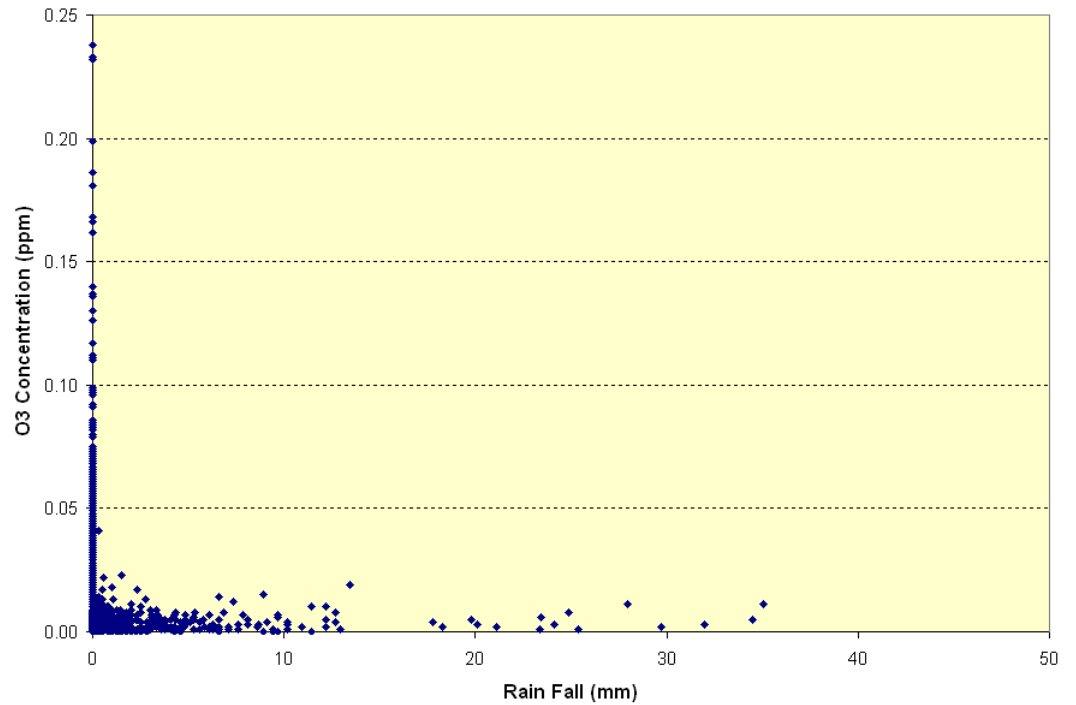
Variation of SO₂ concentrations with rain fall

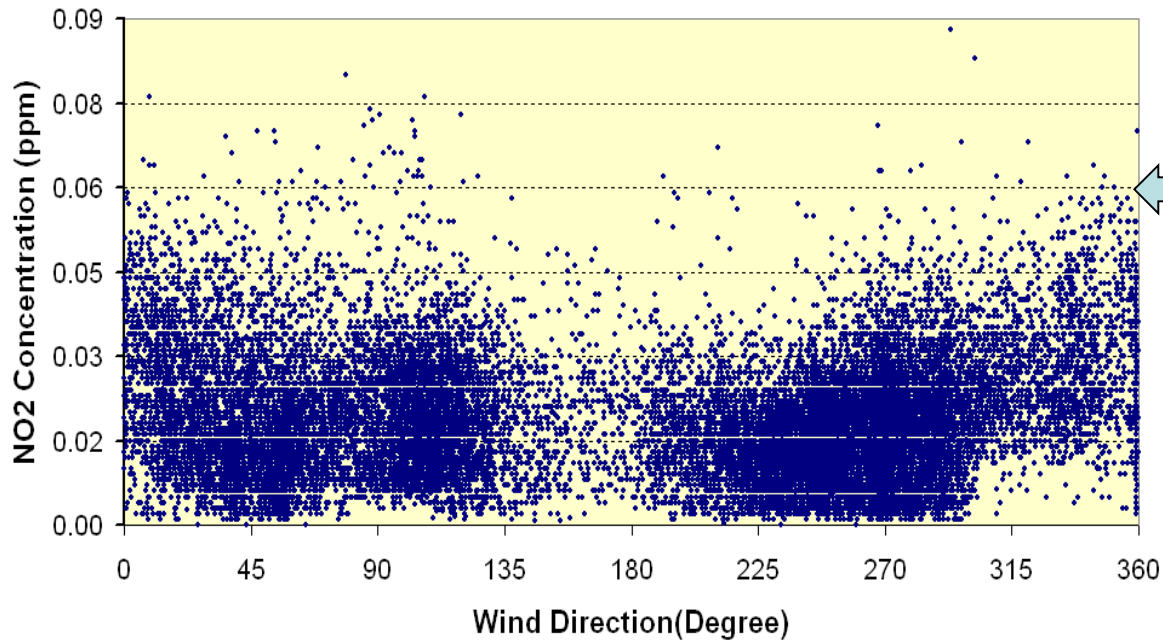




Variation of CO concentrations with rain fall

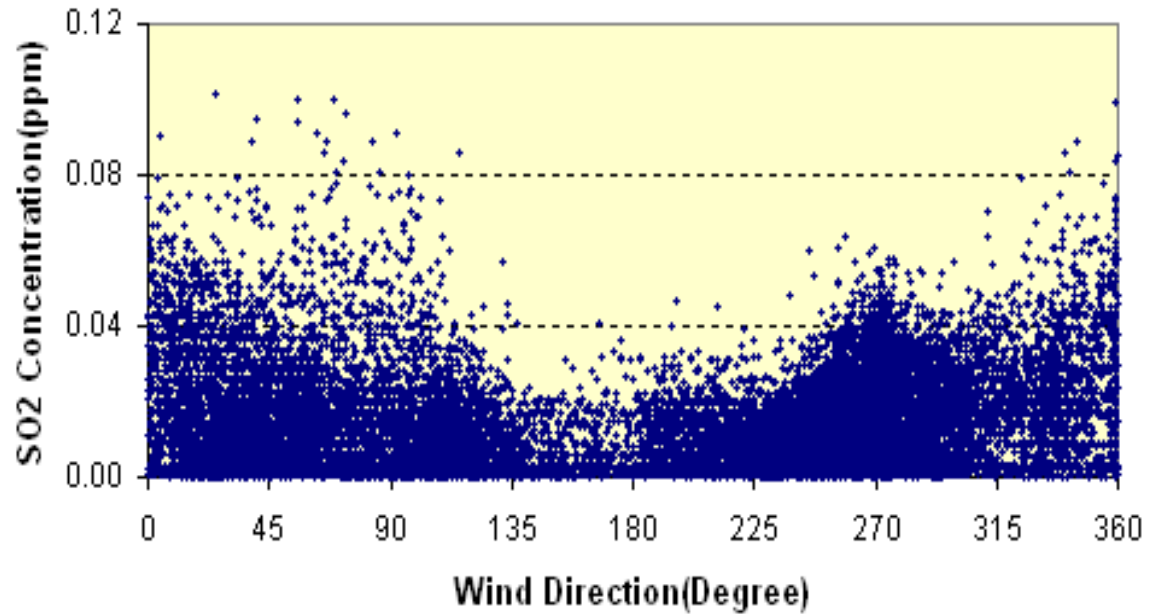
Variation of O3 concentrations with rain fall

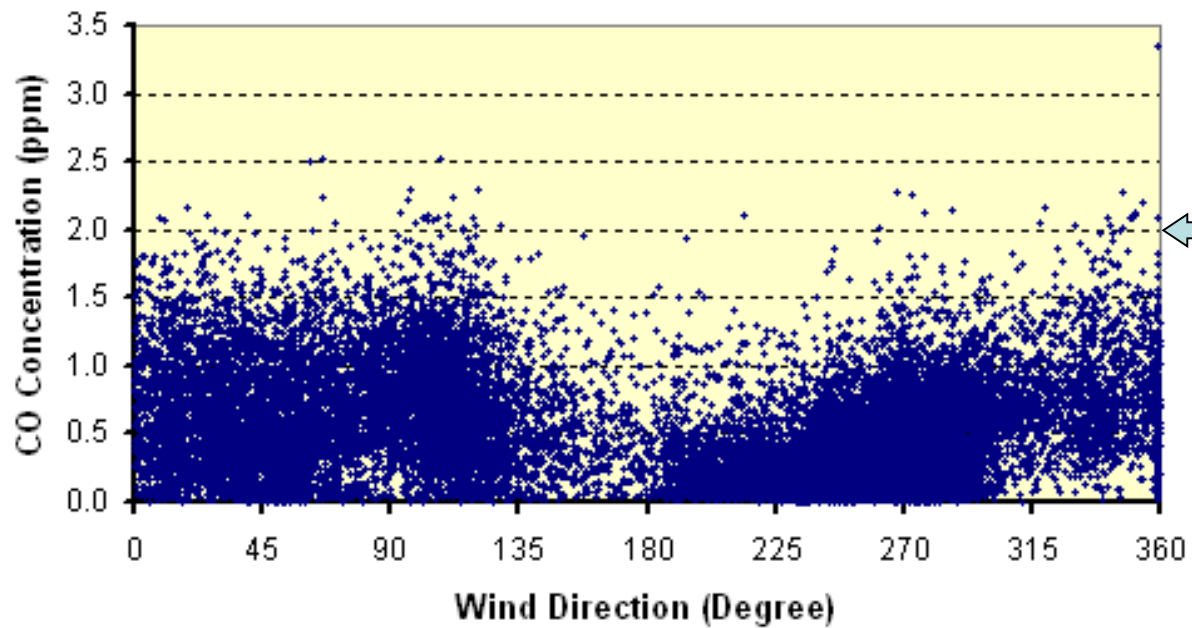




Variation of NO₂ concentrations with wind direction

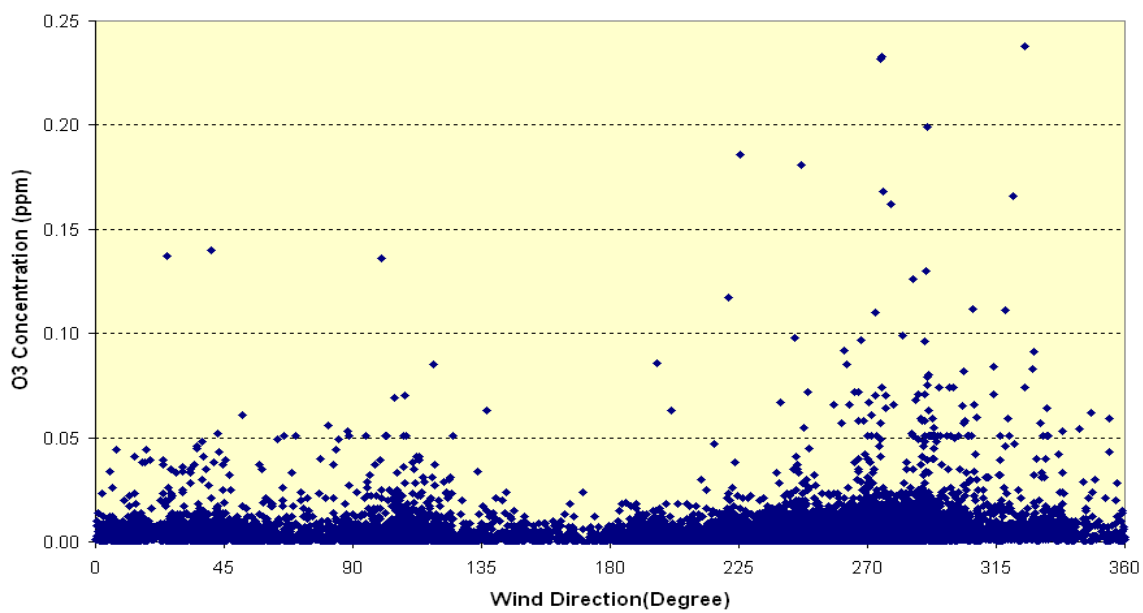
Variation of SO₂ concentrations with wind direction

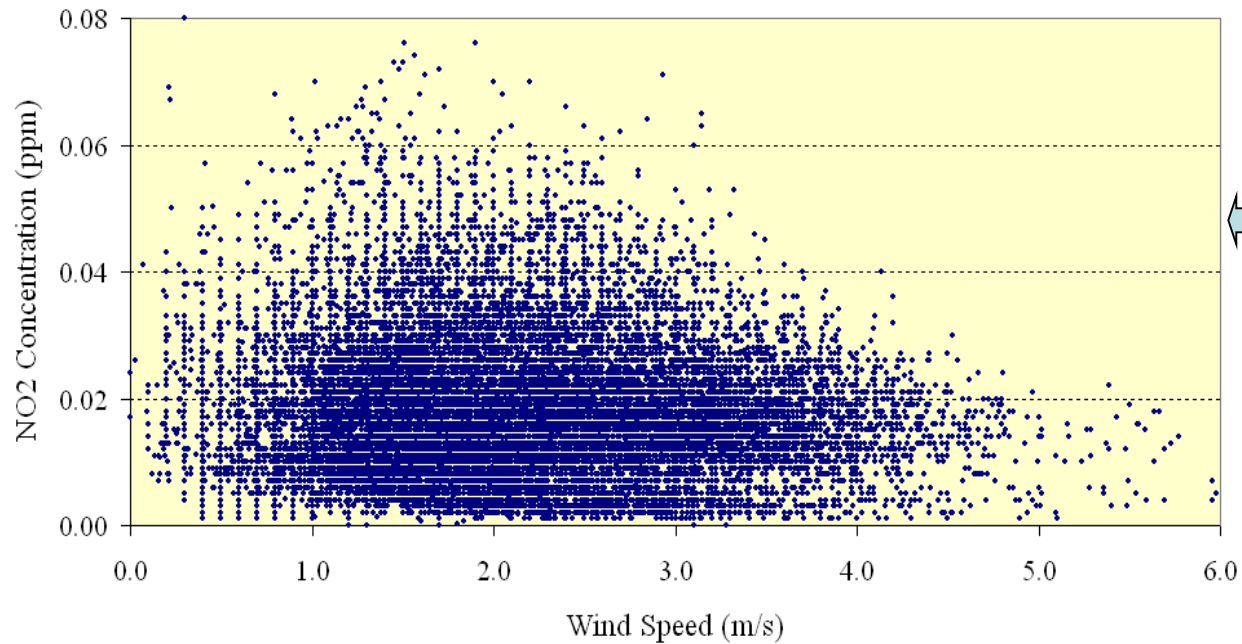




Variation of CO concentrations with wind direction

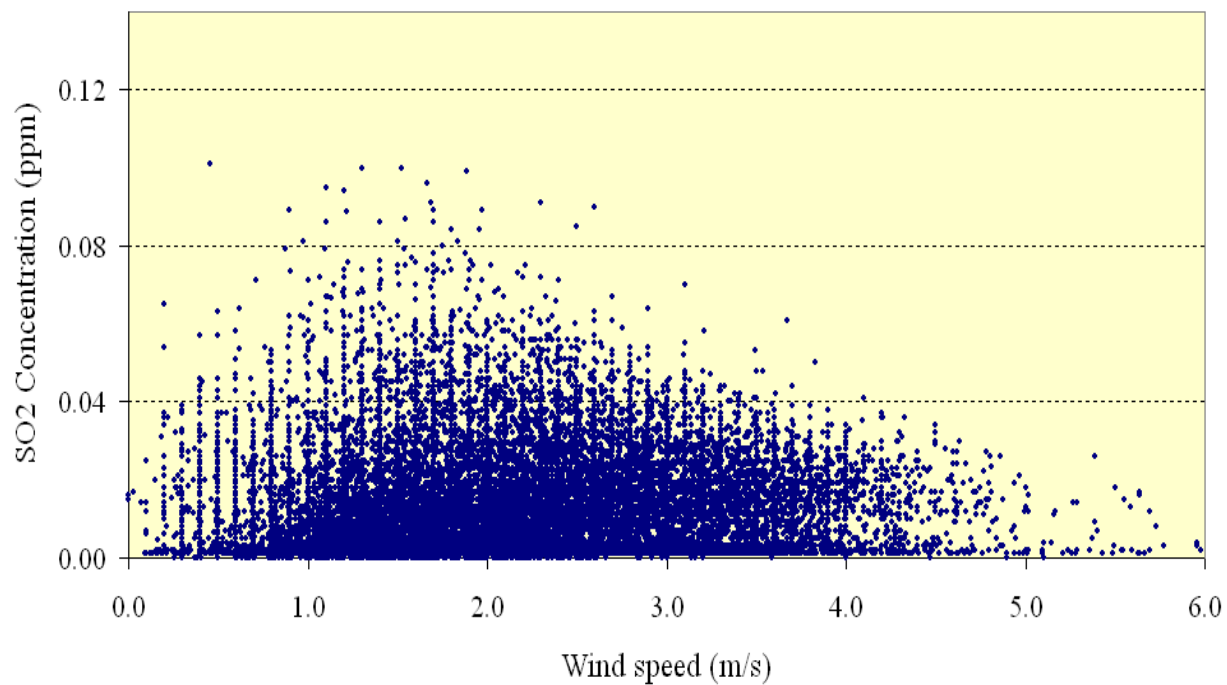
Variation of O₃ concentrations with wind direction

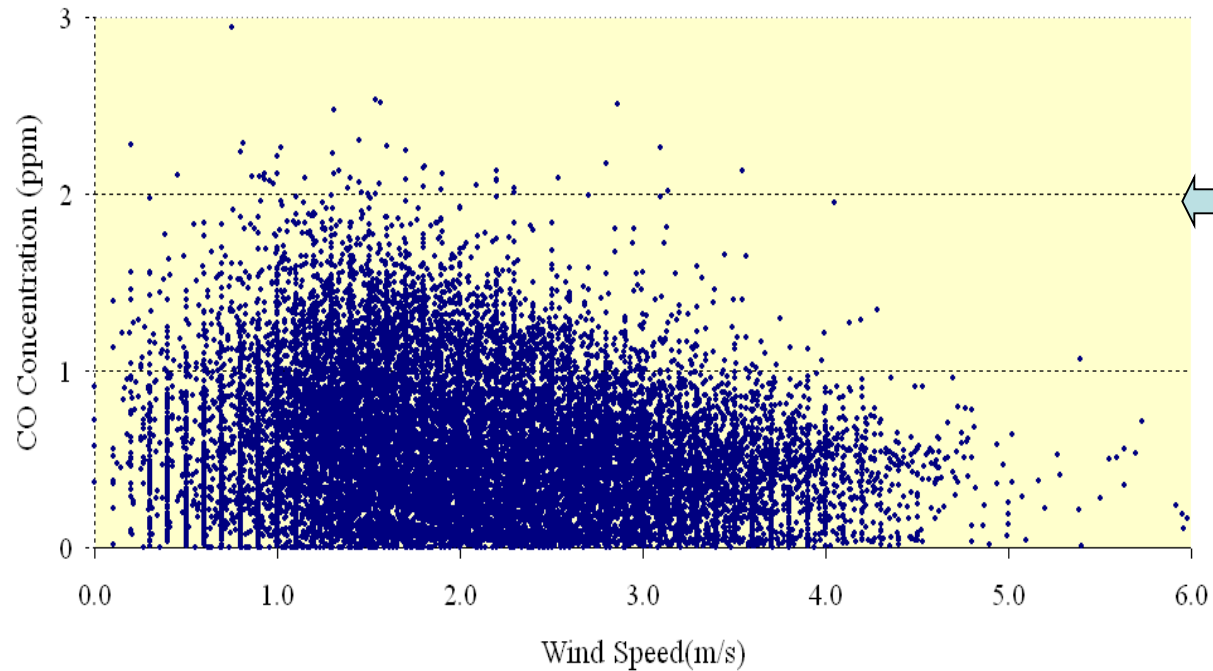




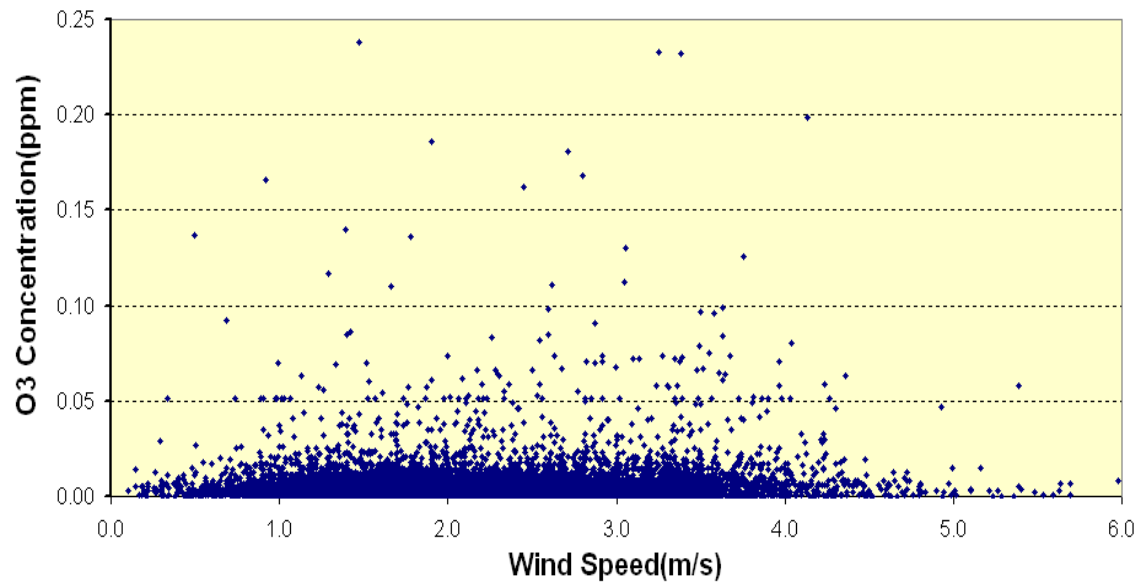
Variation of NO₂ concentrations with wind speed

Variation of SO₂ concentrations with wind speed





Variation of O₃ concentrations with wind speed



This report will provide trend information on air quality

- To assist in the development of appropriate reporting methodology**
- To create systems tackling progress in air quality management**
- To provide guidance and direction for policy makers, decision makers, planners and policy analysts in the private and government sectors.**

Summary of monitoring data for gases pollutants

	Air pollutant	Percentage of data captured	Percentage of missing data	Total No of data points	Mean ppm	Median ppm	Min ppm	Max ppm
Colombo Fort monitoring Station	NO₂	70.3%	29.7%	46161	0.019	0.017	0.00	0.121
	SO₂	69.9%	30.1%	45924	0.013	0.008	0.00	0.331
	CO	63.7%	36.3%	41838	0.546	0.382	0.00	9.515
	O₃	28.1%	71.9%	15172	0.005	0.003	0.00	0.378
Meteorological Department monitoring station	NO₂	38.6%	61.4%	13282	0.008	0.007	0.00	0.047
	SO₂	43.8%	56.2%	15090	0.004	0.003	0.00	0.043
	CO	40.7%	59.3%	14042	0.435	0.310	0.00	5.060
	O₃	39.7%	60.3%	13667	0.021	0.011	0.00	0.364

Summary of monitoring data for PM₁₀

	Total No of data points	Mean μgm^{-3}	Median μgm^{-3}	Min μgm^{-3}	Max μgm^{-3}
Colombo Fort monitoring station *	424	76.8	74	35	153
Colombo Meteorological Department monitoring station **	193	52.3	50	13	111

- PM₁₀ sampling was carried out once in four days from May 1997 to December 2001 and once in three days from May 2003 to June 2004.*

*** PM₁₀ sampling was carried out once in four days from May 1997 to December 2000.*