RESEARCH ARTICLE SCIENCE INTERNATIONAL

DOI: 10.17311/sciintl.2013.356.363

Measurement and Modeling of Nitrogen Dioxide Pollution over Madurai City

[1]Tennyson Daniel, [1]M. Rajesh Kumar and [2]R.V. Jeba Rajasekhar

[1]Regional Test Centre (Solar Thermal) School of Energy Sciences, Madurai Kamaraj University, Madurai, 625021, India

[2]Department of Physics, Govt. Arts College, Melur, Tamil Nadu, India

ABSTRACT

Background: Air pollution due to anthroprogenic sources, is a matter of concern in whole world. The polluted air causes local effects and since it is not bound by national or international boundaries, it also causes global effects. Therefore, a local action with global vision is required for the protection of the environment. The present study is conducted to experimentally quantify the levels of NO_2 for all seasons, to correlate the estimated concentrations of NO_2 on the basis of the sources and seasons and to predict the ambient concentration of NO_2 using Comprehensive Air Quality Model with extensions (CAMx) and compare the estimated and predicted concentration of the NO_2 statistically. **Methods:** Air samples are collected at six sampling sites in Madurai City. Ambient nitrogen dioxide (NO_2) concentration was quantified using the modified Jacob and Hochheiser method. **Results:** It is found that the monthly concentrations range between 53.2 and 66.4 $\mu g\ m^{-3}$. The annual concentrations are mostly below the Indian air quality standards and are comparable with those observed in other Indian urban areas. Nitrogen dioxide concentrations are predicted using CAMx model and it is observed that the CAMx-predicted values are consistent with the observed values at all the sites. **Conclusion:** As CAMx model predicts reasonably, it is concluded that this model can be used for the prediction of Nitrogen dioxide in Madurai city for air quality regulatory purposes.

Key words: Nitrogen dioxide, jacob and hochheiser method, CAM_X, eulerian photochemical dispersion model

Science International 1 (10): 356-363, 2013

INTRODUCTION

Nitrogen dioxide is one of the criteria pollutants and is released into the atmosphere by natural as well as anthropogenic sources[1,2,3,4]. The major natural sources are geothermal activities and bacterial action. The major man-made sources are transportation, industrial processes and domestic and commercial activities[5,6]. Transportation includes petrol and diesel driven vehicles, coal fired and diesel powered locos of railways and landing and takeoff operations of airways. NO_2 plays a major role in atmospheric chemistry, particularly in the formation of secondary air pollutants such as ozone, peroxyacyl nitrate (PAN) and nitrate aerosols, contributing to environmental acidification[7]. It has varying degrees of effect on health depending on short or long term exposures. Therefore, it is essential to estimate nitrogen dioxide concentrations especially in urban areas. A few studies pertaining to the estimation of NO_2 have been done in India. A study was conducted on criteria pollutants at Downtown, New Delhi and it was reported that all measured concentrations were below the US National Ambient Air Quality Standards most of the times[8]. During a study in Calcutta, India, ambient concentration of NO_2 was monitored for two seasons at 19 important traffic intersection points. Fortnightly, measurements were made and the results indicated that the average concentration was 222 and 55 ppb for the winter and summer seasons, respectively[9]. In a study at Mumbai, which is one of the metropolitan cities of India, ambient concentrations of NO_2 were monitored at two specific sites where air pollution activities were dominant. Ambient monitoring of NOx was done continuously for two days at each of these sites. The average concentrations of NOx at both the sites were found to range between 10 and 275 ppb[10]. The ambient concentrations of NOx and CO were estimated at an observational site in Pune, India during the period of June 2003 to May 2004. The average concentrations of NOx during summer were observed to be 5.4-15.64 ppbv (with mean value of 10.39 ppbv). During the southwest monsoon months, the average concentrations were found to be 3.03 ± 0.54 ppbv for Nox[11].

The estimated concentrations in the present study can be compared with those found in the national

Corresponding Author: Tennyson Daniel, Regional Test Centre (Solar Thermal) School of Energy Sciences, Madurai Kamaraj University, Madurai, 625021, India Tel: +91 9655632660

© 2013 Science International

reviews. The present study was conducted with the objectives of (1) Creating a comprehensive database pertaining to the levels of NO_2 for all the seasons at selected sites of the city (2) Correlating the estimated concentrations of NO_2 on the basis of the sources, seasons and statistical analysis (3) Predicting the ambient concentration of NO_2 using Comprehensive Air Quality Model with extensions (CAMx) and (4) Comparing the estimated and predicted concentration of the NO_2 statistically.

MATERIALS AND METHODS

Monitoring nitrogen dioxide: Madurai city (9°54' N, 78°84' E and 100 m MSL), one of the ancient cities in Tamil Nadu, is now a bustling city and a major commercial centre. The 4000 years old city is the second largest city of Tamil Nadu and very much modern and progressive with a surface area of 52.8 km^2 and a population of 1.2 million in 2001[12]. The ambient air quality of the city is being deteriorated like other cities of India due to combustion of fossil fuels in stationary and mobile sources[13]. To study the distribution of nitrogen dioxide over Madurai city, measurements have been carried out at six different sampling sites. The selection of these sites has been made by giving due consideration to the existing anthropogenic activities occurring at these sites, which are mainly responsible for atmospheric pollution. Concentrations have been measured on a weekly basis at the sampling sites for a duration of one year. A description of the land use, nature of activities and likely sources of atmospheric pollution in the vicinity of the sites are given below.

Site 1

Periyar bus station: This is the main bus station situated at the heart of the city. The area of this bus station is very limited and is surrounded by narrow roads. Therefore, there is always traffic jam at this site, which in turn leads to congestions that cause slow movement of traffic. The contribution to air pollution from this site is the emissions from personal, commercial and public transportation like two wheelers, auto-rickshaws, buses and trucks. Accumulation of air pollutants and photo-chemical activities may be higher at this site due to the presence of tall roadside shops, houses and buildings.

Site 2

Goripalayam: This is a very busy commercial site located in the northern part of the city. In addition to some Government establishments such as Government Rajaji Hospital (the biggest hospital in southern Tamil Nadu), colleges and schools, a large number of shops, restaurants and workshops are also situated around this site. Although, the roads are relatively wider than those in the central parts of the city, the movement of traffic is highly congested and slow due to high vehicular density and encroachment at the roadsides.

Site 3

Palanganatham: This site is surrounded by residential colonies and small scale industries, mostly related to furniture works, grill works, plastic and rubber works and lathe works. In addition, there are a few electroplating units and rice mills. Continuous flow of traffic can be witnessed at this site. Besides the emission from automobiles, the emissions from commercial and domestic sectors also contribute to the total air pollution load at this sampling site.

Site 4

Kochadai: This is an industrial site where two major industries are situated. The National Highway (NH-47) extension passing near this site has a substantial flow of traffic. Hence, emissions from the industries and automobiles are a major source of air pollution in this region. There are also some residential colonies at this site.

Site 5

Pudur: Pudur is a fast emerging extension area of the city with many residential colonies. There are a number of Government offices, educational institutions and commercial establishments at this site. The traffic flow consists of light tonnage vehicles especially two wheelers and heavy tonnage vehicles mainly the public buses. Since the roads are narrow and their conditions are poor, traffic emissions are substantial. An industrial estate is situated at the outskirts of Pudur which may also contribute to background concentrations.

Site 6

Meenakshi amman temple: Having a large number of temples, Madurai is popularly referred to as the Temple city of south India. Meenakshi Amman temple, the landmark of the city, is located at the central part of the city. Around the temple, there are many commercial establishments. This causes the site to be very crowded with continuous traffic flow almost round the clock. The emissions from the automobiles, commercial establishments and residences contribute to the air pollution load of this sampling site.

Topographical features of madurai city: The topography of Madurai city very slightly increases in all directions from the heart of the city except toward the south and a gently sloping terrain surrounds this city. There are no hills in the region of Madurai corporation

© 2013 Science International

limit. Therefore, the existing topography of this city experiences horizontally homogeneous wind flow and more or less steady state meteorological conditions. Such a condition does not allow the accumulation of pollutants[14]. However, at the central regions of the city, building geometry on both sides of the narrow roads is an important parameter for characterizing the transport and dispersion of pollutants. This geometry can be treated as a tunnel, which is open at the top. The elevated pollutant concentrations at some of the sampling sites, which are located in the central parts of the city, may also be determined by this parameter[15,16] .

Measurement of nitrogen dioxide: The Respirable Dust Sampler (Envirotech Model APM 460BL), which is suitable for the sampling time ranging from 30 min to 24 h was used for sampling. The 24 h sampling of pollutant emission either from the stationary source or from the mobile source or from both is carried out with appropriate sampling rates at all the sites and subsequent analyses are executed in the laboratory for estimation of the pollutant using the modified Jacob and Hochheiser method.

Meteorological observations: Meteorology plays an important role in air pollution studies. In fact, there is a strong seasonality in the meteorological factors, which modulates the pollutant levels[17,18]. The important meteorological variables that are studied are wind (speed and direction), rain (amount and duration), air temperature, relative humidity and incident solar radiation[19]. The analysis of the meteorological observations during the period of January 2012 to December 2012 shows that the velocity of wind is maximum during the months of August (7.85 m sec^{-1}), followed by June (6.00 m sec^{-1}) and September (5.88 m sec^{-1}) and range between 0.08 and 7.85 m sec^{-1}. Higher wind speeds are observed in the southwest monsoon season. In the summer months, the observed wind speed is relatively lower than those in the winter season and varies from 0.11-6.00 m sec^{-1}. The predominant wind directions during the period of this study are northeast, north, southwest and west. The maximum number of rainy days (38) and the average maximum rainfall (534 mm) are noticed in the month of October followed by November due to presence of the northeast monsoon. The highest atmospheric temperature of 39.6°C is recorded during the summer season (March-May). The variation of relative humidity shows a steep decrease from winter to summer (66.8-49.8%) and then a slow increase in the rainy season (56.3-62.4%). A maximum solar radiation of 986.4 W m^{-2} is also observed during the summer season.

Modelling of air quality: The Comprehensive Air Quality Model with Extension (CAMx) is validated for the pollutant NO_2 at six sampling sites in Madurai city.

CAMx allows for assessment of gaseous and particulate air pollution over many scales ranging from sub-urban to continental. It is designed to unify all of the technical features required of "state-of-the-science" air quality models into a single system that is computationally efficient and easy to use. The model code has a highly modular and well documented structure which eases the insertion of new or alternate algorithms and features. The input file formats are based on the Urban Airshed Model (UAM) and are compatible with many existing pre and post-processing tools. CAMx requires several separate input files that configure each simulation, define the chemical mechanism and describe the photochemical conditions, surface characteristics, initial/boundary conditions, emission rates and various meteorological fields over the entire modeling domain.

CAMx simulates the emission, dispersion, chemical reactions and removal of pollutants in the atmosphere by solving the pollutant continuity equation for each chemical species (l) on a system of nested three-dimensional grids. The Eulerian continuity equation describes the time dependency of the average species concentration (cl) within each grid cell volume as a sum of all of the physical and chemical processes operating on that volume. This is expressed mathematically in terrain-following height (z) coordinates in Eq. 1:

$$\frac{\partial C_l}{\partial t} = -\nabla_H \cdot V_H \cdot C_l + \left\{\frac{\partial(C_l\eta)}{\partial Z} - C_l\frac{\partial}{\partial Z}\left(\frac{\partial h}{\partial t}\right)\right\} + \nabla \cdot \rho K \nabla(C_l/\rho) + \frac{\partial C_l}{\partial t}_{\text{Chemistry}} + \frac{\partial C_l}{\partial t}_{\text{Emission}} + \frac{\partial C_l}{\partial t}_{\text{Removal}} \quad (1)$$

where, V_H is the horizontal wind vector, η is the net vertical entrainment rate, h is the layer interface height, ρ is atmospheric density, and K is the turbulent exchange (or diffusion) coefficient. The first term on the right-hand side represents horizontal advection, whereas the second term represents the net resolved vertical transport across an arbitrary space and time-varying height grid and the third term represents sub-grid scale turbulent diffusion. Chemistry is treated by simultaneously solving a set of reaction equations defined from specific chemical mechanisms. Pollutant removal includes both dry surface uptake (deposition) and wet scavenging by precipitation.

Pollutant emissions are treated in two basic ways within CAMx. Low-level (gridded) emissions that are

© 2013 Science International

released into the lowest (surface) layer of the model and elevated stack-specific (point) emissions with buoyant plume rise that can be emitted into any model layer. Emissions are injected into each cell of every grid at every time step during the simulation. CAMx produces gridded time-averaged concentration output files. A separate average output file is written for each grid employed in the simulation in UAM format. Surface deposition fields for the same user-selected species are also written to output files with the same structure as the average concentration files. Gridded three-dimensional instantaneous concentrations of all species on all grids are written at the end of the simulation to allow for a model restart. Commonly available graphical visualization and animation software can be used to view CAMx average and deposition output files.

Statistical analysis: A statistical analysis was done using MS Excel for the CAMx model validation. The analysis includes estimation of average measures, correlation measures, difference measures and degree measures. A perfect agreement between the measured and predicted values should result in an index of agreement value of 1.0, thereby confirming the suitability of the model.

RESULTS AND DISCUSSION

Urban air quality is a dynamic and complex environmental phenomenon exhibiting temporal and spatial variations which are mainly due to changes in the rate of emission from sources, variations in the meteorological and topographical conditions and dissimilarities in the rate of removal of pollutants from the atmosphere[20,21,22]. In this connection, the ambient air quality data of Madurai city under all weather and meteorological conditions is evaluated. In addition, CAMx air quality model is validated. These databases are beneficial (1) To define inter-relationship among the sources of pollution, atmospheric parameters and measurable manifestations for evaluating the character and the magnitude of the existing problem, (2) To obtain knowledge and understanding necessary for developing preventive and corrective measures and urban planning and to evaluate the efficiency of existing abatement measures, if any and (3) To validate air quality model for its subsequent utilization in the study area[23,24,25,26,27].

Status of NO_2 concentrations: While observing the overall level of NO_2 recorded at all the sampling sites and for all seasons, it is found that the concentrations range between 30.2-98.3 $\mu g\ m^{-3}$. This indicates that NO_2 levels in some parts of the city are exceeding the permissible limits set by Central Pollution Control Board (CPCB), India.

NO_2 pollution in Madurai city is the result of vehicular sources which are the major source like most other cities of India. The estimated NO_2 source strength in domestic and commercial sectors of the city shows that the combustion of firewood, dung, peat and other bio mass fuels besides charcoal, kerosene and LPG contributes considerably to the NO_2 pollution load. A very few industries which are spread sporadically all over the city, emit NO_2 into the atmosphere and it is meaningful to note that there is no major industrial source like power plant, which produces high NO_2 emissions.

While comparing the growth of the number of two wheelers with other type of vehicles in past two decades, it is studied that it is quite high and now the number of two wheelers is in manifolds. The NO_X emission factor ($g\ km^{-1}$) for two wheelers is relatively very low in comparison with medium and heavy tonnage vehicles[28,29]. But, the calculated automobile source strength values show that the two wheelers contribute notably to the total NO_X pollution load of Madurai city, since their number is very high and many of them are operated with two stroke engines.

Even though the transport service is increased, it is keeping pace with the demand, which is growing in geometric progression. One of the consequences of this is overloading of buses all the time which is very common in most parts of the city. Public buses which are diesel driven require serious attention in maintenance, regular oil change etc. But, it is obvious that most of the buses are badly maintained and over aged. Since Madurai is the commercial centre of south Tamil Nadu and well connected by road transport all over, a large number of lorries and trucks are in operation for material transportation. These heavy tonnage vehicles (public buses, lorries and trucks) in addition to personal and commercial (mostly diesel driven vehicles) four wheelers are the major cause of NO_2 emission in the city. The elevated pollutant concentrations at some of the sampling sites can be correlated to these specific parameters.

Seasonal variation in NO_2 concentrations: The overall concentrations of NO_2 throughout the year at the six sampling sites are presented in Table 1. The monthly variations of the concentrations of NO_2 are depicted in Fig. 1a-f. From these figures, it is noticed that the month of December shows the highest recorded concentrations, whereas the month of June shows the lowest concentration of NO_2 in all the sites.

To understand the seasonal variability of the concentrations of the pollutant, seasonal distribution has

© 2013 Science International

Table 1: Summary of NO_2 concentrations at six sites of Madurai city

	NO_2 concentrations ($\mu g\ m^{-3}$)						
	Percentile						
Site	25th	50th	75th	Maximum	Mean	Minimum	S.D
1	54.1	64.9	80.2	98.3	66.4	38.8	15.9
2	52.3	65.4	80.8	94.1	66.4	38.4	16.3
3	50.2	60.5	76.0	90.8	63.1	37.2	15.5
4	44.4	50.7	62.4	79.8	53.2	30.2	12.9
5	50.0	58.8	69.9	86.5	60.3	39.8	12.5
6	45.6	52.5	62.3	79.5	54.4	35.7	11.1

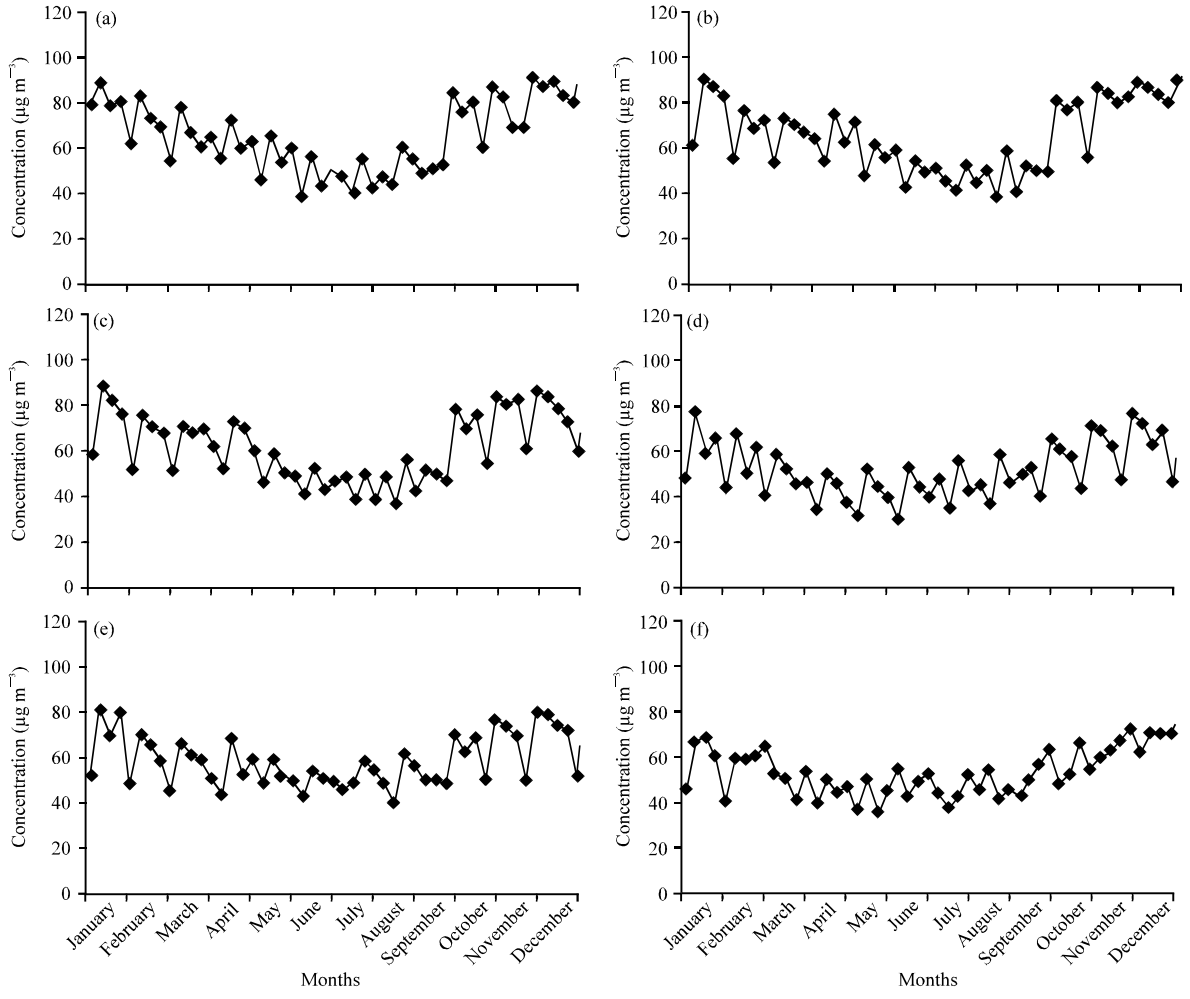

Fig. 1(a-f): Seasonal variation of NO_2 concentrations at (a) Site 1, (b) 2, (c) 3, (d) 4, (e) 5 and (f) 6

been calculated and it has been presented in Table 2. It is observed from Table 2 that NO_2 has the maximum concentrations in the winter season (mid November to mid February) and minimum concentrations during summer season (mid March to mid June). The recorded concentrations are found to cross the tolerance limits set by CPCB mostly during winter season but they are found to be mostly within the permissible limits during the summer season.

© 2013 Science International

The enhanced concentrations during winter can be correlated with meteorological conditions like low wind speed, low temperature, high humidity and feeble solar radiation available during this season. In addition, the mixing height can be associated, as it was low due to small values of sensible heat flux and a large lapse rate owing to the long stable surface layer due to radiative cooling. All these factors cause poor dispersion conditions and favour the occurrence of high concentrations of this pollutant. As the rate of homogeneous conversion of this gaseous pollutant by photochemical radicals is very low, reduction in the ambient concentrations in this way is negligible in this season.

The reduced concentrations during summer can be attributed with the strong influence of O_3 on NO_2. The high solar flux in addition to high ambient temperature during the summer season exerts a quite definite action on transformation rates and promotes the efficiency of atmospheric chemical reactions. The summer season is also associated with relatively higher wind speed, lower relative humidity and rare inversions. The higher wind speed with lower relative humidity causes rapid dispersion, transport and dilution of this gaseous pollutant.

Comparison of estimated and CAMx-predicted NO_2 concentrations: Air quality with special reference to NO_2 is monitored during four seasons at six sampling sites in Madurai city. Subsequently, NO_2 is predicted using CAMx model equation. The estimated and predicted concentrations for the four seasons are presented in Table 3.

The observed and predicted concentrations in the present study range from 64.0-82.9 $\mu g\ m^{-3}$ and 62.8-82.0 $\mu g\ m^{-3}$ during the winter season, from 45.7-61.1 $\mu g\ m^{-3}$ and 46.7-62.2 $\mu g\ m^{-3}$ during the summer season, from 47.4-52.5 $\mu g\ m^{-3}$ and 46.8-51.7 $\mu g\ m^{-3}$ during the south west monsoon season and from 60.7-80.0 $\mu g\ m^{-3}$ and 58.1-84.3 $\mu g\ m^{-3}$ during the north east monsoon season. High observed and predicted concentrations of NO_2 are obtained at the receptor points of Site 1-2. This is comparable with the traffic emissions in these sampling sites. Wind speed determines the extent to which pollutants are initially diluted with ambient air at the point of release. Since wind speeds are lower, there are high predicted concentrations at some sites, compared with the measured NO_2 levels.

A statistical analysis is done for the CAMx model validation and it is presented in Table 4. It is observed from the statistical analysis that difference between the predicted and observed mean concentration is $<2\ \mu g\ m^{-3}$ for the gaseous pollutant NO_2. The calculated correlation measures show that there is a good correlation (0.88-0.98) between the observed and predicted concentrations. As far as the difference measures are concerned, it is noted that the values of systematic error is close to zero and the value of the unsystematic error nearly approaches the value of the overall root mean square error. The index of agreement (d) between the observed and predicted concentrations is also calculated. A perfect agreement between the measured and predicted values would result in an index of agreement value of 1.0. For all data in Table 3, the d value ranges from 0.94-0.98. The value corresponds to a good agreement between the measured and predicted values. CAMx model can be used to predict the concentrations of NO_2 not only over the city but also over the corporation region, including sub-urban areas.

Table 2: Seasonal variations of NO_2 concentrations in Madurai city

Site	Winter	Summer	*SW monsoon	**NE monsoon
1	82.9	60.0	52.1	77.9
2	81.4	61.1	50.5	80.0
3	75.5	58.8	48.9	75.5
4	64.0	45.7	47.4	62.1
5	70.9	54.9	52.5	67.9
6	64.6	48.8	48.4	60.7

*SW: South West, **North East

Table 3: Experimentally observed and theoretically predicted concentrations of NO_2 using CAMx model

	NO_2 concentrations ($\mu g\ m^{-3}$)							
	Winter		Summer		*SW monsoon		**NE monsoon	
Receptor points	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed
Site 1	80.3	82.9	62.2	60.0	51.4	52.1	75.0	77.8
Site 2	82.0	81.4	58.6	61.1	51.6	50.5	84.3	80.0
Site 3	73.1	75.5	54.3	58.8	49.3	48.9	72.7	75.5
Site 4	62.8	64.0	48.0	45.7	46.8	47.4	60.5	62.1
Site 5	71.5	70.9	55.9	54.9	51.7	52.5	68.3	67.9
Site 6	63.2	64.6	46.7	48.8	49.8	48.4	58.1	60.7

*SW: South West, **North East

© 2013 Science International

Table 4: Statistical analysis on the validated CAMx model

Statistical measures	Winter	Summer	*SW monsoon	**NE monsoon
Average measures				
Observed mean (O)	72.1	54.3	50.1	69.8
Predicted mean (P)	73.2	54.9	49.9	70.7
Correlation measures				
Slope (B)	0.98	0.95	0.96	0.82
Intercept (A)	2.32	3.49	1.80	13.36
Correlation coefficient (γ)	0.98	0.90	0.88	0.96
Difference measures				
Observed deviation	7.44	5.49	1.74	8.86
Predicted deviation	7.42	5.79	1.89	7.55
Bias	-2.13	-1.20	0.27	-1.70
Fractional bias	-0.015	-0.01	0.003	-0.0121
Normalised mean square error (NMSE)	0.000215	0.000121	0.000007	0.000146
Mean square error-systematic (MSEs)	1.07	0.67	0.15	1.80
Mean square error-unsystematic (MSEu)	1.27	2.56	0.88	2.01
Total mean square error (RMSE)	1.67	2.65	0.90	2.70
Degree measures				
Index of agreement (D)	0.98	0.94	0.94	0.97

*SW: South West, ** North East

CONCLUSION

In the case of monitoring of NO_2, it is found that the concentrations cross the permissible limits at some of the sampling sites during the monitoring period. As population, traffic, industrialization and per capita energy consumption will increase in future, it will simultaneously increase the emission load which in turn will increase the ambient air pollution substantially over a period of time. If the atmosphere is polluted in this range, it is certain that it will have long-range adverse effects on the health and both the personal and social wealth of the people living in this city. Stringent implementation of adequate abatement measures and environmental regulations are necessary for the pleasant present and sustainable future.

In the case of modeling of NO_2, a statistical measure namely index of agreement is calculated between the measured and CAMx-predicted concentrations of NO_2 and it is found to be 0.98. The value indicates that a good agreement exists between the observed and predicted values and therefore CAMx can be used to simulate pollutant concentrations for Madurai city.

As for as monitoring and modeling of NO_2 are concerned, continuous monitoring of the pollutant concentrations, simultaneous recording of meteorological variables, assessment of traffic density and generation of extensive emission inventory should be carried out periodically not only to evaluate the existing air quality management strategies but also to implement air pollution abatement strategies.

ACKNOWLEDGMENTS

The authors thank the authorities of School of Energy, Environment and Natural Resources, Madurai Kamaraj University for the facilities and encouragement provided.

REFERENCES

1. Logan, J.A., M.J. Prather, S.C. Wofsy and M.B. McElroy, 1981. Tropospheric chemistry: A global perspective. J. Geophy. Res., 86: 7210-7254.
2. Logan, J.A., 1983. Nitrogen oxides in the troposphere: Global and regional budgets. J. Geophys. Res., 88: 10785-10807.
3. Lee, D.S., I. Kohler, E. Grobler, F. Rohrer and R. Sausen *et al.*, 1997. Estimations of global NO_x emissions and their uncertainties. Atmos. Environ., 31: 1735-17494.
4. Aneja, V.P, D.S. Kim and W.L. Chameides, 1997. Trends and analysis of ambient NO, NOy, CO and ozone concentrations in raleigh, North Carolina. Chemosphere, 34: 611-623.
5. Mayer, H., 1999. Air pollution in cities. Atmospheric Environ., 33: 4029-4037.
6. Madany, I.M. and S. Danish, 1993. Spatial and temporal patterns in nitrogen dioxide concentrations in a hot desert region. Atmos. Environ. Part A Gen. Topics, 27: 2385-2391.
7. Madany, I.M. and S. Danish, 1993. Spatial and temporal patterns in nitrogen dioxide concentrations in a hot desert region. Atmos. Environ. Part A Gen. Topics, 27: 2385-2391.
8. Aneja, V.P., A. Agarwal, P.A. Roelle, S.B. Phillips, Q. Tong, N. Watkins and R. Yablonsky, 2001. Measurements and analysis of criteria pollutants in New Delhi, India. Environ. Int., 27: 35-42.
9. Mondal, R., G.K. Sen, M. Chatterjee, B.K. Sen and S. Sen, 2000. Ground level concentration of nitrogen oxides (NO_x)at some traffic intersection points in Calcutta. Atmos. Environ., 34: 629-633.
10. Lal, S. and R.S. Patil, 2001. Monitoring of atmospheric behavior of NO_x from vehicular traffic. Environ. Monit. Assess., 68: 37-50.

© 2013 Science International

11. Beig, G., S. Gunthe and D.B. Jadhav, 2007. Simultaneous measurements of ozone and its precursors on a diurnal scale at a semi urban site in India. J. Atmos. Chem., 57: 239-253.
12. Rajasekhar, R.V. and P. Muthusubramanian, 2004. Nitrogen oxides and lead air pollution in Madura city. Asian J. Microbiol. Biotechnol. Environ. Sci., 6: 317-319.
13. Rajasekhar, R.V.J., T. Daniel and P. Muthusubramanian, 2005. Vehicular emission loads of gaseous pollutants in Madura city. Asian J. Microbiol. Biotechnol. Environ. Sci., 7: 427-430.
14. Benson, P.E., 1989. CALINE 4: A dispersion model for predicting air pollutant concentrations near roadways. Report No. FHWA/CA/TL-84-15, Division of New Technology and Research, Department of Transportation, State of California, Sacramento, CA., USA., June 1989.
15. Cooper, C.D. and F.C. Alley, 1986. Air pollution control: A design approach. PWS Publishers, Boston, USA.
16. Buckland, A.T. and D.R. Middleton, 1999. Nomograms for calculating pollution within street canyons. Atmos. Environ., 33: 1017-1036.
17. Espinosa, A.J.F., M.T. Rodriguez and F.F. Alvarez, 2004. Source characterization of fine urban particles by multivariate analysis of trace metal speciation. Atmos. Environ., 38: 873-886.
18. Karar, K., A.K. Gupta, A. Kumar, A.K. Biswas and S. Devotta, 2005. Statistical Interpretation of Weekday/Weekend differences of ambient gaseous pollutants, vehicular traffic and meteorological parameters in urban region of Kolkata. J. Environ. Sci. Eng., 47: 164-175.
19. Singal, S.P. and R. Prasad, 2005. Analytical study of some observed micrometeorological data. J. Air Pollut. Control, 1: 44-49.
20. Fang, G.C., C.N. Chang, C.C. Chu, Y.S. Wu, P.P.C. Fu, I.L. Yang and M.H. Chen, 2003. Characterization of particulate, metallic elements of TSP, $PM_{2.5}$ and $PM_{2.5-10}$ aerosols at a farm sampling site in Taiwan, Taichung. Sci. Total Environ., 308: 157-166.
21. Koliadima, A., A. Athanasopoulou and G. Karaiskakis, 1998. Particulate matter in air of the cities of Athens and Patras (Greece): particle size distribution and elemental concentrations. Aerosol Sci. Technol., 28: 292-300.
22. Vakeva, M, K. Hameri, M. Kulmala, R. Lahdes, J. Ruuskanen and T. Laitinen, 1999. Street level versus rooftop concentrations of submicron aerosol particles and gaseous pollutants in an urban street canyon. Atmos. Environ., 33: 1385-1397.
23. WHO., 1977. Air Monitoring Programme Design for Urban and Industrial Areas. World Health Organisation, Geneva, Switzerland, ISBN-13: 9789241700337, Pages: 46..
24. Ashar, N.G., 1983. Air pollution?monitoring and control. Indian J. Environ. Prot., 3: 73-78.
25. Das, D.B., A. Bhargava, A.B. Gupta and K. Gupta, 1997. Sulphur dioxide, nitrogen dioxide and carbon monoxide concentrations during evening peak traffic hours in Jaipur city. Indian J. Environ. Prot., 17: 833-840.
26. Boralkar, D.B., 1993. Multidisciplinary approach to air quality monitoring. J. Inst. Public Health Eng. India, 4: 56-62.
27. Agarwal, S.K., 1996. Industrial Environment: Assessment and Strategy. Aph Publishing Co., New Delhi.
28. Pundir, P.P., A.K. Jain and D.K. Gogia, 1994. Vehicle emissions and control perspectives in India: A state of art report. Indian Institute of Petroleum, Dehradun, India.
29. Sivacoumar, R., 1990. Application of line source model for vehicular pollution prediction near roadways. M.E. Thesis, Centre for Environmental Studies, Guindy Engineering College, Anna University, Chennai, India.

© 2013 Science International