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Research Article

SEASONAL VARIATION OF TOTAL OXIDANTS: CONTRIBUTIONS OF OXIDES OF NITROGEN, SULPHUR (IV) OXIDE EMISSIONS AND BACKGROUND OZONE FROM ILORIN, NIGERIA

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ABSTRACT

The model runs with single point source showing the variation of concentrations of air pollutants (NO_2, NO_x, O_3, and SO_2) with distance in ambient air of Ilorin. This city is a medium size town, located in the central guinea savannah zone of Nigeria. The model runs was done using data collected during dry and wet seasons using Air Dispersion Modeling System (ADMS) – Urban. The pattern of NO_2 and NO_x are different at the two seasons, a Gaussian type curve was observed during dry season while a Sigmoid curve obtained during the wet season. However, the elevation was higher for dry than wet season due to higher photochemical activities. The results obtained in ppb are: NO_x 10.48, SO_2 6.82, O_3 60.28; wet; NO_x 3.12, SO_2 5.32, O_3 15.72. These predicted concentration values from theoretical model compared fairly well with the measured values and empirical model values.

Keywords: Air Dispersion Modeling System, Pollutants, Models, Photochemical Activities, Gaussian and Sigmoid curves

INTRODUCTION

Dispersion Modeling is a typical example of theoretical models. If the physical, chemical and or biological mechanisms underlying a process are well understood, a steady – state or dynamic model can be developed. Steady – state models cannot be used for predicting system responses over time, and therefore, have limited management value. Time – variable models, on the other hand, can handle variable input loads, and can be useful for establishing cause – effect relationships. When compared to empirical models, theoretical models are generally more complex. They require a longer period of observation for calibration and the number of variables and parameters to be measured are greater. They also require a significant amount of time for validation. Due to their complexity, and because the understanding of atmospheric systems is incomplete, these types of models are less frequently used than empirical models[1].

Theoretical model also goes along with Geographic Information System (GIS) as well as Geographic Positioning System (GPS). The purpose of a dispersion model is to calculate air pollution concentrations according to the pollution emissions data and the nature of the atmosphere[2]. Among many advanced dispersion models, ADMS – Urban, AA Quire and Indic AirViro are designed to model at an urban scale and include point, line and area sources[3]. However, according to a survey carried out[4], it was concluded that ADMS – Urban is the most widely used advanced model.

The ADMS – Urban model is a steady – state new generation Gaussian type model which was originally developed (as UK - ADMS) for point source applications[5]. The model has since been developed as a multi – source dispersion modeling system for air quality management applications all over the world.

The model (ADMS) has been subjected to a number of validation studies[6, 7]. ADMS – Urban is a development of the ADMS model[7] including a line source algorithm to enable the calculation of pollutant concentrations from road traffic and industrial sources. ADMS – Urban is an urban scale, multi – source model allowing up to 3000 grid sources, 1000 road sources and 100 industrial sources to be simultaneously modeled with complete terrain and street canyons. ADMS – Urban is also called "new generation" dispersion model which means it uses an approach to boundary layer scaling based on the Monin – Obukhov length and boundary layer depth, rather than the Pasquill stability classes used by many earlier dispersion models[2]. Another feature of ADMS – Urban is that in convective conditions, the concentration profiles are assumed to be skewed – Gaussian in order to bring material from elevated releases rapidly down to the surface[9]. The model is further integrated with a Geographical Information System (GIS), ArcView 3, and an emission database. This interface is an important visualization tool and also provides a means of manipulating the spatial element of the model input data[5].

METHODS

Emissions data for this study were the measured data generated between 2003 and 2006[10]. The coordinates and description of sampling locations for the collection of our data have been discussed in our earlier works[11, 12, 13]. The meteorological data were collected from Nigeria Meteorological Services (NIMET) unit of Aviation Ministry, ARIAL, Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile – Ife as well as from global Baseline Surface Radiation Network (BSRN) of NASA located in Physics Department, University of Ilorin.

The sources in the inventory are spatially described as point and area sources. The inventory is within a GIS allowing aggregation of emission from all sources, sectors up to a grid square basis. A constant value for surface roughness was used for the entire study area (z_o=1.0m). This is not representative of the whole study area and may result in inaccuracies in the modeling calculations [14]. A surface roughness length of 1.0 m is representative of an urban area such as Ilorin but some parts of the study area will be less built – up and a lower value for surface roughness would be more appropriate, this has been previously remarked[5] and they commented that such problem is likely to recur with the use of this type of model over a regional scale. The model allows two input values for the surface roughness; one at the source location and the other at the receptor location, but it does not allow for variation in surface roughness for different source locations. However, the algorithm for the evaluation of downwind concentration is displayed in Figure1.

As shown in Figure1, the system has a number of distinct features used to achieve the modeling of data[14] moreso, concentration – distance line plot (Figures 2 – 9) as well as a contour map Figures shown latter displayed the expected three conditions i.e. stable, neutral and convective.

RESULTS AND DISCUSSION

Single elevated point source modeling

Figures 2 - 9; shows the concentration – distance line plot, that is, the dispersion of the pollutants from a single elevated point source. The three ambient stability classes are represented. The deep blue colour represents the unstable condition of the atmosphere; green colour represents the neutral atmospheric condition while the light blue colour represents the stable atmospheric condition.

As a result of the input data into ADMS – Urban as shown in Figure 1, new concentrations were calculated taking into consideration the values of surface roughness, the latitude of the site, Monin – Obukhov length, height of recorded wind, meteorological data, emissions, background concentrations, grid etc. The new concentration calculated is referred to as modeled concentration. Below is Figures 2 to 5 showing the dispersion of pollutants from single elevated point source during raining season in Ilorin.

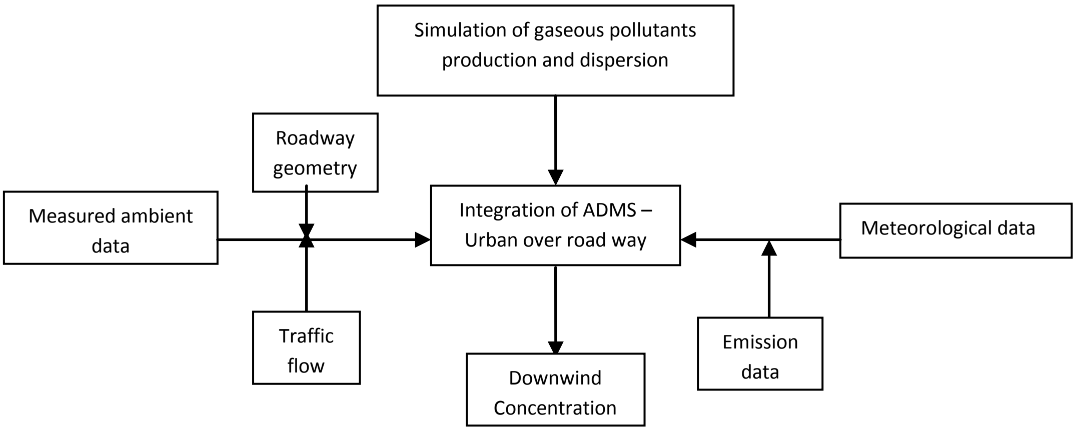

Fig. 1: The algorithm for the evaluation of downwind concentration using the adms – urban model

Ilorin rain

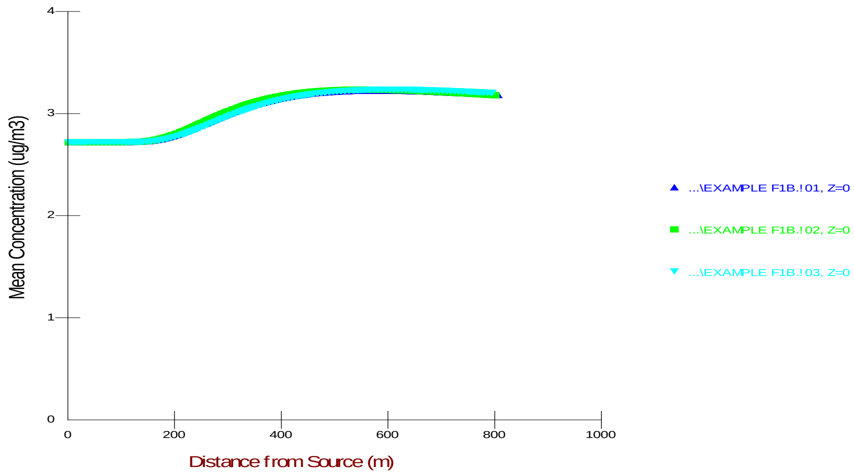

Fig. 2: Concentration – distance line plot for NO_2 in the rainy season for Ilorin

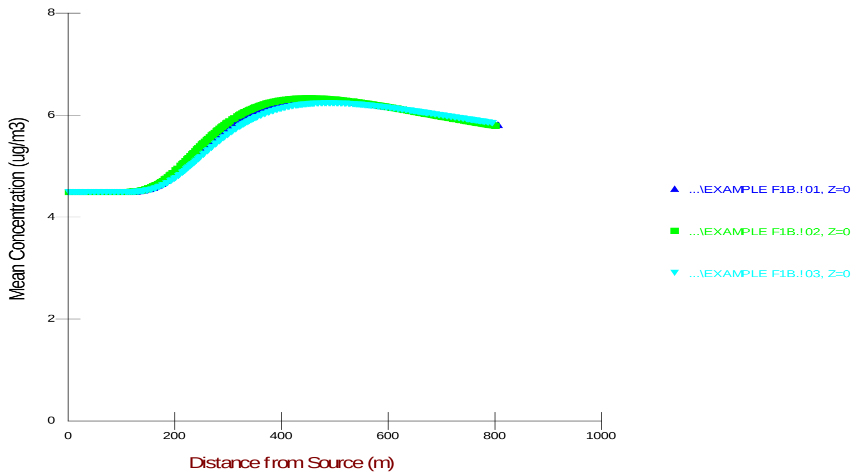

Fig. 3: Concentration – distance line plot for NO_X in the rainy season for Ilorin

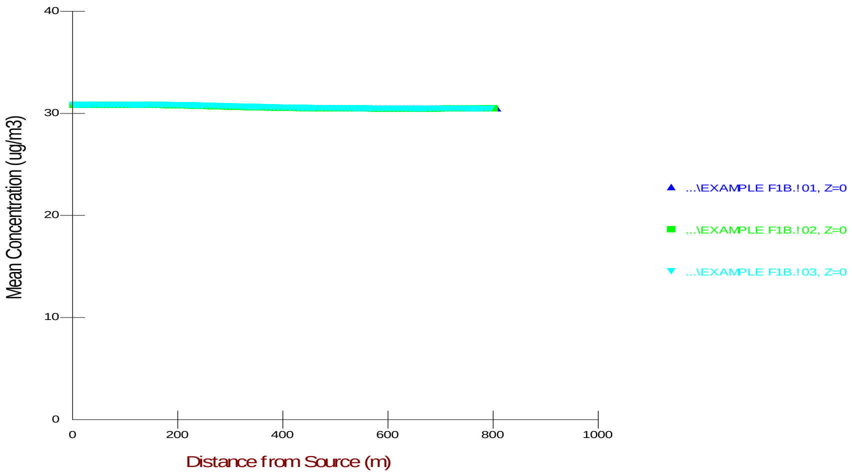

Fig. 4: Concentration – distance line plot for O_3 in the rainy season for Ilorin

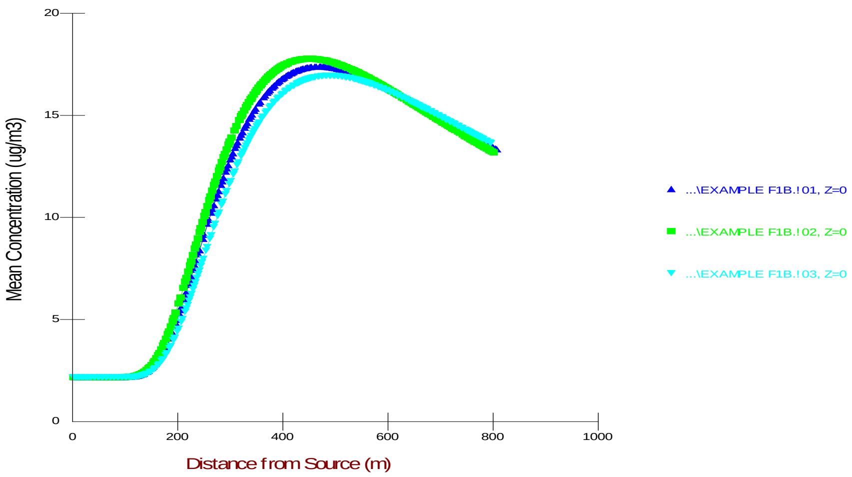

Fig. 5: Concentration – distance line plot for SO_2 in the rainy season for Ilorin

Below is Fig.s 6 to 9 showing the dispersion of pollutants from single elevated point source during dry season in Ilorin.

Ilorin dry

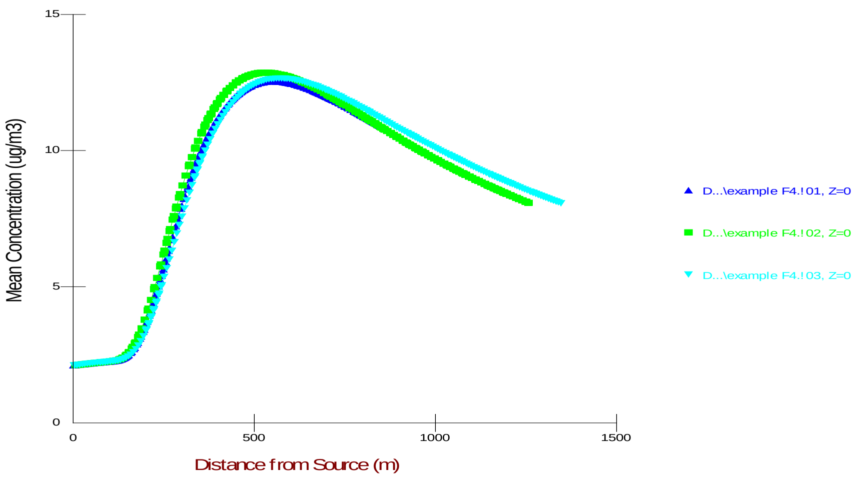

Fig. 6: Concentration – distance line plot for NO_2 in the dry season for Ilorin

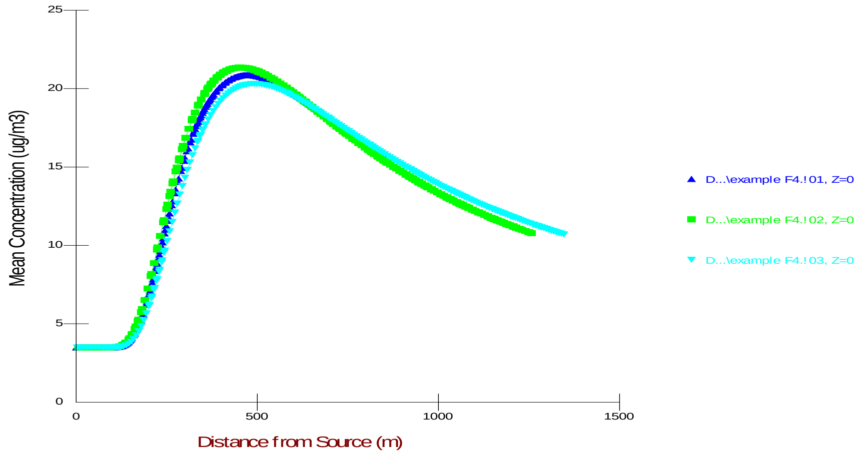

Fig. 7: Concentration – distance line plot for NO_X in the dry season for Ilorin

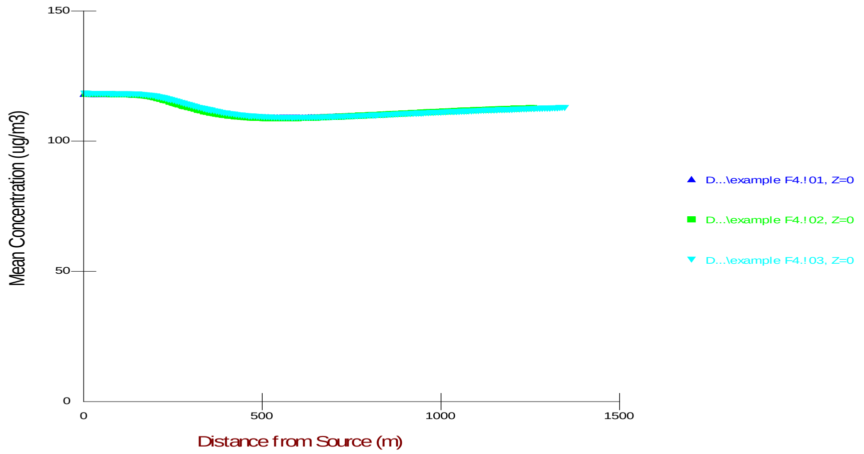

Fig. 8: Concentration – distance line plot for O_3 in the dry season for Ilorin

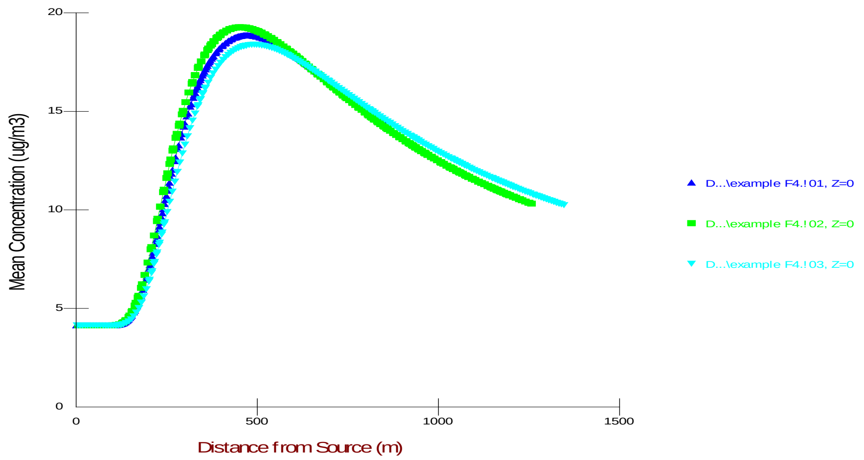

Fig. 9: Concentration – distance line plot for SO_2 in the dry season for Ilorin

The model runs with a single elevated point source presented in Figures 2 – 9 showing the variation of concentrations of NO_2, NO_x, O_3 and SO_2 with distance in Ilorin town during both rainy and dry seasons. Figures 4 and 8 shows that the ozone concentration is nearly constant during the rainy season, however, it shows a very slight decrease before attaining a constant value beyond a distance of about 500 m in the dry season. The behaviour of NO_2 and NO_x are also different between the two seasons. A Gaussian type curve was produced during the dry season while an S – type curve was obtained during the rainy season. The elevation is also higher for dry than rainy season. This could be attributed to a higher photochemical activity involving the interconversion of NO_2 or NO_x into O_3[15] in the dry season. There is no visible change for the variation of SO_2 for both dry and rainy season (Figs. 5 and 8).

Comparison of monitored and modeled data

Table 1: The measured and ADMS - Urban modeled concentration values of O_3, NO_x and SO_2 during rainy and dry seasons in Ilorin city[11, 12]

Sites	O_3		NO_x		SO_2	
	Measured	**Modeled**	**Measured**	**Modeled**	**Measured**	**Modeled**
Ilorin Rain	21.86 ± 2.57[a]	15.72	3.31 ± 0.40	3.12	1.29 ± 0.17[b]	5.32
Ilorin Dry	32.44 ± 14.03[a]	60.28	2.03 ± 0.23	10.48	7.17 ± 0.87[b]	6.82

[a] 12, [b] 11

Table1 shows that the modeled concentrations are generally higher in dry season and this follows a similar trend with field measurements. The relatively lower values during wet season have been attributed to the attenuation effect of rain. The modeled result for SO_2 in dry season is however higher by 28% than that of rainy season.

For comparative purpose, the mean measured concentrations and predicted concentrations by ADMS – Urban are summarized in Table 1. The predicted concentration for O_3 and NO_x are higher than measured values during dry season while and concentration of SO_2 is higher during the wet season. This could be due to poor mixing of atmospheric air as a factor of wind speed downwind during the sampling period. The effect of ozone is more felt in rural than urban because of its being a secondary pollutant unlike the oxides of nitrogen and sulphur. Effect of rain attenuation is more on other pollutants than ozone because of the nature of rural still being felt in Ilorin.

CONCLUSION

Going by the complexity of the theoretical modeling, more information may be required for computation in other to have a good agreement between the predicted concentration and measured concentrations for NO_x, O_3, and SO_2. However, the result confirmed that the technique could be used to obtain useful information to support air quality management decisions, in – depth understanding of source strengths and potential impacts, as well as projecting in to the future.

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