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AN ASSESSMENT OF THE CONTRIBUTION OF VEHICULAR TRAFFIC TO AMBIENT AIR QUALITY - A CASE STUDY OF NAIROBI EXPRESSWAY CORRIDOR

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Abstract

In this study, the vehicular air pollution from the Nairobi Expressway corridor was estimated by simulation using AERMOD dispersion model. The Vehicle Kilometer Travelled (VKT), emission factors, and traffic data were used to estimate the pollutants from vehicular traffic.. The highest modelled 24-hour and annual concentrations of $PM_{2.5}$ were 0.274 µg/m^3 and 0.152 µg/m^3, whereas the highest 24-hour and annual concentrations of PM_{10} were 0.405 µg/m^3 and 0.225 µg/m^3, respectively. The maximum 24-hour and annual concentrations of Total Volatile Organic Compounds (TVOCs) were 20.8 µg/m^3 and 11.5 µg/m^3, respectively, whereas the maximum 8-hour and annual concentrations of carbon monoxide (CO) were 319 µg/m^3 and 177 µg/m^3, respectively. The highest modeled 24-hour and annual concentrations of NO_2 were 28.2 µg/m^3 and 15.7 µg/m^3, respectively. The 24-hour average measured TVOCs values showed that Nairobi expressway traffic contributed 3.5 percent to the measured TVOCs concentration value, but CO accounted for 55 percent of the measured value. According to the simulated $PM_{2.5}$ and PM_{10} concentration values, Nairobi expressway traffic contributed 1.1 and 1.6 percent, respectively, to the 24-hour average measured concentration levels.

Keywords:

AERMOD;
Air Pollution;
Dispersion;
Emissions.

1 Introduction

Air pollution is currently considered the main environmental health risk because it is estimated to cause 7 million deaths every year [1]. Vehicular traffic is a significant mobile source of air pollution in urban areas. Studies on communities residing close to busy roadways have also been conducted to look into the effects of prolonged exposure to pollutants. Air pollution has been linked to health problems including stroke, chronic obstructive pulmonary disease, trachea bronchus and lung cancers, aggravated asthma and lower respiratory infections [2]. Increased motorization and urbanization continue to contribute to the sharp rise in environmental contaminants, especially air pollution [3]. Vehicular emissions are highly variable due to issues such as old and worn-out engines, inappropriate fuel grades, a lack of routine maintenance, the physical aging of engines, intensive car usage, mistreatment of lubricants, and a restriction on ideal fuel combustion. Ideally, carbon dioxide (CO_2) and water (H_2O) are supposed to be the only products of complete combustion of hydrocarbon fuel, however, due to inevitable incomplete fuel combustion the result is the production of carbon monoxide (CO), hydrocarbons, NO_2, and SO_2 emissions from the exhaust system and engine parts of vehicles [4]. Secondary pollution is normally exhibited as photochemical smog, visibility reduction and haze which is due to the mixing of the emissions [5]. For instance, ozone and photochemical smog is as a result of the

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reaction of nitrogen oxides with hydrocarbons, volatile organic compounds, and other pollutants in the presence of ultraviolet radiation [6]. It is imperative to note that the reduction of traffic-related pollutants (TRAP) requires a combination of multiple interventions, such as the introduction of policies on vehicle emissions control [7], engineering approaches such as road design modifications [8], vehicle technologies [9], and green infrastructure [10], and even behavioral aspects such as the shift to active transport [11] and community-level policies and practices [12].

Air dispersion modelling is vital in spatial dispersion of air pollutant concentrations and evaluation of the exposure of the target populations to the emissions. Air dispersion modeling of the pollutants is better than air quality monitoring, which is done only at the location of the sensors, because how the air pollutants spread from the sources is better understood. Once human exposure to the pollutants is known, measures towards prevention or reduction of the harmful effects can be implemented. The American Meteorological Society/United States Environmental Protection Agency Regulatory Model (AERMOD) air dispersion model is reliable in the simulation of roadside vehicle-induced pollution [13]. Using planetary boundary layer turbulence structure and scaling assumptions, the steady-state plume model AERMOD treats both surface and elevated sources as well as simple and complex terrain [14]. AERMOD is suitable for linear sources of emissions [15]. It does modeling by relying on a singular wind field to move the released species. Meteorological readings made at the surface, in the upper air, and onsite are used to generate the wind field. Additionally, AERMOD integrates meteorological data with geophysical data such as topography elevations and land usage to determine boundary layer parameters. The model involves two input data pre-processors: AERMET and AERMAP [14].

AERMOD simulation has been widely applied in air dispersion studies [16-20]. Yadav et al.'s [16] study estimated industrial air pollutant ground-level concentrations using AERMOD in India. Amoatey et al. [18] estimated the seasonal variation of air pollutants from Tema Oil Refinery in Ghana using AERMOD. Craig et al. [19] modeled and measured near-road $PM_{2.5}$ concentrations in Indianapolis and Providence in the United States, and the study findings indicated that modeled roadway contributions exceeded measured values based on the near-road monitoring data. Modeled NO_2 concentrations exceeded measured values owing to traffic sources, according to Abayomi et al. [17], who studied air pollutant emissions from generator use in Nigeria. Amouzouvi et al. [20] evaluated pollutants along a highway in Togo using the AERMOD dispersion model and found that the modeled concentrations of SO_2 were almost twice the WHO limit, indicating the use of poor fuel quality. This study estimates the contribution of traffic along the Nairobi Expressway corridor to ambient air pollution in Nairobi. The traffic data was obtained from manual vehicle counts carried out at three locations along the Nairobi Expressway corridor. This study employed the National Pollution Inventory (NPI) method to estimate the pollutants from vehicles, which estimates the pollutants using information such as the vehicle type, emission factor, fuel type, and vehicle kilometers traveled (VKT). The air dispersion modeling was done using AERMOD software. A comparison of modeled values and roadside measured air pollutant concentrations along the Nairobi Expressway corridor was also performed. This study contributes to knowledge on the air quality state in road corridors in Kenya and also the applicability of AERMOD in the simulation of air pollution from mobile sources. In addition, this study can guide current and future policies on vehicle emissions.

2 Methods

2.1 Study Area

The Nairobi Expressway corridor is approximately 21 kilometers long from Mlolongo to James Gichuru (Fig. 1). The study focused on the estimation of the concentration of pollutants (TVOC, CO, NO_2, and PM emissions) along the corridor. The Nairobi Expressway corridor is one of the most heavily trafficked corridors in Nairobi by vehicles from Mombasa port and Tanzania (through the Namanga border). The terrain along the Nairobi expressway and in the surrounding areas is considered to be relatively flat. Fig. 1 below is the topographic map of the study area showing the Nairobi Expressway corridor with an indication of the three sites where both the traffic count and air quality monitoring were done simultaneously.

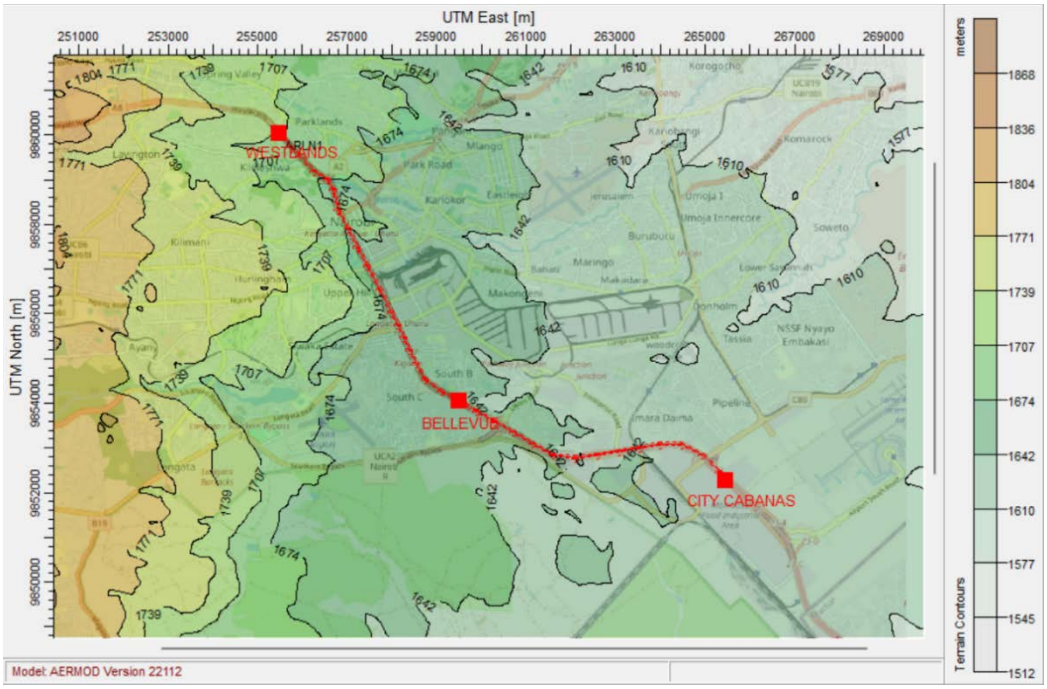


Fig. 1: Topographical map of Nairobi showing data collection sites along proposed Nairobi Expressway.

Bellevue station is located close to the city center; its location is characterized by residential land use. Westlands station has mixed commercial and residential land use, while City Cabanas station has a predominantly industrial area and commercial land use. The details of the three air quality monitoring stations along the Nairobi Expressway corridor are in Table 1.

Table 1: Description and locations of sampling sites along Nairobi Expressway corridor.

	Sampling Site Location	Abbreviation Code	Latitude	Longitude	Description
1	City Cabanas	CC	-1.335730923	36.8921738	5 lanes in both directions, with lane width varying between 3.0 and 3.5 meters (3 lanes on the lower deck and 2 lanes on the upper deck).
2	Bellevue	BLV	-1.319397583	36.83853807	5 lanes in both directions, with lane width varying between 3.0 and 3.5 meters (3 lanes on the lower deck and 2 lanes on the upper deck).
3	Westlands	WSL	-1.265509383	36.80268084	5 lanes in both directions, with lane width varying between 3.0 and 3.5 meters (3 lanes on the lower deck and 2 lanes on the upper deck).

2.2 Air Quality and Traffic Data Collection

Air quality at the three locations was measured using Open-Seneca Sensors air quality monitoring units, which are mobile, wireless, and battery-powered systems for measuring outdoor air quality. The sensors continuously measure and record the Global Positioning System (GPS) location, meteorological data (humidity and temperature), and air quality data, including concentrations of Particulate Matter ($PM_{2.5}$ and PM_{10}), Typical Particle Size (TPS), Number of Concentrations of Particles ($NC_{2.5}$ and NC_{10}), Total Volatile Organic Compounds (TVOC), and equivalent Carbon Monoxide (eCO). The concentrations of the pollutants were averaged to hourly concentrations to allow for a comparison with modeled data. Seven days' manual traffic counts were carried out so as to get data on the weekly traffic and daily traffic flows on the Expressway corridor. The traffic count data was collected in both direction (Mlolongo to James Gichuru and James Gichuru to Mlolongo) at 15-minute intervals, which were aggregated into hourly and daily volumes. The daily traffic data was then averaged so as to obtain the average daily traffic (ADT) which is an important input in the vehicle emissions calculation. In addition to the traffic volume, the vehicle classification (fleet mix) was obtained. The vehicle classification is important in showing the role of vehicle type (e.g., motorcycles, passenger cars, buses, light goods, medium goods, and heavy goods vehicles) on air quality. Ten receptors, assumed to be at ground level, were spaced uniformly along the Nairobi Expressway corridor, and three discrete receptors at the three

sites where the air quality was being monitored were computed by AERMOD. The air quality monitoring stations were used as receptor points for model simulations so that a comparison of the measured and modeled data could be done.

2.3 Model Input Data and Set Up

2.3.1 Meteorological Data as Model Input

Meteorological factors are important in air pollution concentrations and dispersion. Wind speeds and direction influence the transportation and mixing of pollutants and thus urban air ventilation [15]. The meteorological file used for the study contained hourly data of surface and upper sounding meteorological variables for the years 2020 to 2022. This data was input into the meteorological pre-processor AERMET, which calculated the boundary layer parameters. The behavior of the plume from vehicle emissions was estimated from the output parameters. The reason for using this MET data is due to its compatibility with AERMOD Version 10.2.0 software.

2.3.2 Terrain data as Model Input

The topographic map of the study area was prepared using Shuttle Radar Topography Mission (SRTM) data sets, which produced a digital elevation model (DEM) of the study area as shown in Fig. 1. As indicated in Fig. 1, Nairobi's elevation ranges from 1512 m to about 1868 m above sea level. The topography of the modeling domain was then preprocessed by AERMAP.

2.3.3 Vehicle Emissions Sources as Model Input

According to Zhao et al. [22], vehicle emission factors (EFs) vary due to factors such as road features, traffic conditions, vehicular performance, driver behaviour, environmental factors, and even emission standards. These factors make the accurate determination of emission factors for vehicles difficult to estimate. This study employed the National Pollution Inventory (NPI) method to estimate the pollutants from vehicles, which estimates the pollutants using the vehicle type and distance travelled by the vehicle using Equation 1 [23].

$$E_v = 365 * 0.01 \sum\{v_{x,y} * \sum_m \sum_x \sum_p (x_{x,m,f} * e_{x,m,f,p})\} \quad (1)$$

Where:
E_y – Annual emissions from motor vehicles in grid cell *y*, kg per year,
$v_{x,y}$ – Average daily VKT for road *x* in grid cell *y*, km per day,
$x_{x,m,f}$ – Relative VKT of vehicle type *m* and fuel type *f* on road *x*,
$e_{x,m,f,p}$ – Emission factor for vehicle type *m*, fuel type *f* and emission process type *p* (exhaust, evaporative, on tyre and brake wear) on road *x*, gkm,
365 – Conversion factor for Day to year,
0.01 – Conversion factor for Grams to kilograms.

With the manual traffic count data, the following Equation 2 was used to estimate VKT from traffic counts:

$$v_{x,y} = \sum t_{x,y,i} * L_{x,y,i} \quad (2)$$

where:
$V_{x,y}$ – Average daily VKT for road *x* in grid cell *y,* km per day,
$t_{x,y,i}$ – Average daily traffic count for road link *i* of road *x* in gird cell *y*, per day,
$L_{x,y,i}$ – Length of road link *i* of road type *x* in grid cell *y*, km.

The total Vehicle Kilometer Travelled (VKT) for the different vehicle categories was calculated using Equation 2. No other pollution sources were taken into account in the simulation; only the mobile sources that were moving along the 14 km-long Nairobi Expressway corridor from Cabanas to Westlands were taken into account. Further an assumption that the vehicles in the network did not exit the corridor at any point was used. Based on the average of the seven-day traffic count, a simulation was run with an average daily traffic (ADT) of 61,317. In terms of vehicle composition, the ADT for each

vehicle classification was as follows: 62.2% of vehicles were passenger cars, 11.8% were light commercial vehicles (LCVs), 20% were heavy commercial vehicles (HCVs), and 5% were motorcycles. The emission rates were calculated using the average vehicle kilometers, relative vehicle kilometers and emission factors. The average daily VKT was calculated using the Average Daily Traffic (ADT) and length of the road from Cabanas to Westlands station. For the relative VKT by vehicle type and road type, the following default values were used [24]: Passenger cars (0.806), Light Commercial vehicles (0.131), heavy duty (0.052) and motorcycles (0.011). These values are for arterial major roads with average speed (30 km/hr) and congestion levels which result in about 20% idle time and represent the worst case in terms of congestion in the corridor. Vehicles were classified according to the following categories: Motorcycles (two-wheeled motorbikes), Passenger Cars (minimum four-wheeled designed for passengers), Light Commercial Vehicles (vehicles which carry goods with a gross weight of less than 3500 kg) and Heavy Commercial vehicles with a gross weight of more than 3500 kg.

The data used on vehicle fuel type statistics of Kenya was obtained from the Energy Regulatory Commission (ERC) report on the fuel economy in Kenya [25]. Using the traffic data and vehicle statistics (mainly the fuel type), the emissions for different air pollutants were calculated. The calculated emissions are estimations since recording individual vehicle emissions while in operation is difficult. The emission factors used are based on the National Pollution Inventory, and they consider emissions for each type of vehicle category and take into consideration different types of vehicle emissions.

2.4 Model Setup

The latest version of the software was used, comprising three parts: AERMOD Meteorological Pre-processor (AERMET version 10.2.0), AERMOD Terrain Pre-processor (AERMAP version 10.2.0), and AERMOD (version 10.2.0). AERMET uses a meteorological file dataset prepared using the Weather Research and Forecasting (WRF) prognostic models to process the hourly surface data and upper air data to output SFC and PFL files that are used in AERMOD. The AERMAP processes the terrain elevation data in conjunction with a layout of receptors and sources for AERMOD control files. In this work, the commercial interface ISC-AERMOD View (Version 10.2.0) (Lakes Environmental Software) was used in modeling the dispersion of the pollutants. Ground concentrations of pollutants were determined for each specified pollutant averaging period across the modelling period for each receptor in the modeling domain. Maximum modelled ground level concentrations (GLCs), which represent the "worst-case" meteorological circumstances for atmospheric emissions, were then graphically depicted as contours over the grid or as discrete points at each sensitive receptor. The dispersion modeling outputs were 8-hour (for carbon monoxide only) and 24-hour and annual ground-level concentrations for the other pollutants. These durations were used to enable a comparison of the simulated ground-level concentrations to permissible limits set out by the regulations of the National Environment Management Authority (NEMA). The flow chart in Fig. 2 below demonstrates the air dispersion modeling procedure, highlighting the model inputs, preprocessors, and model outputs.

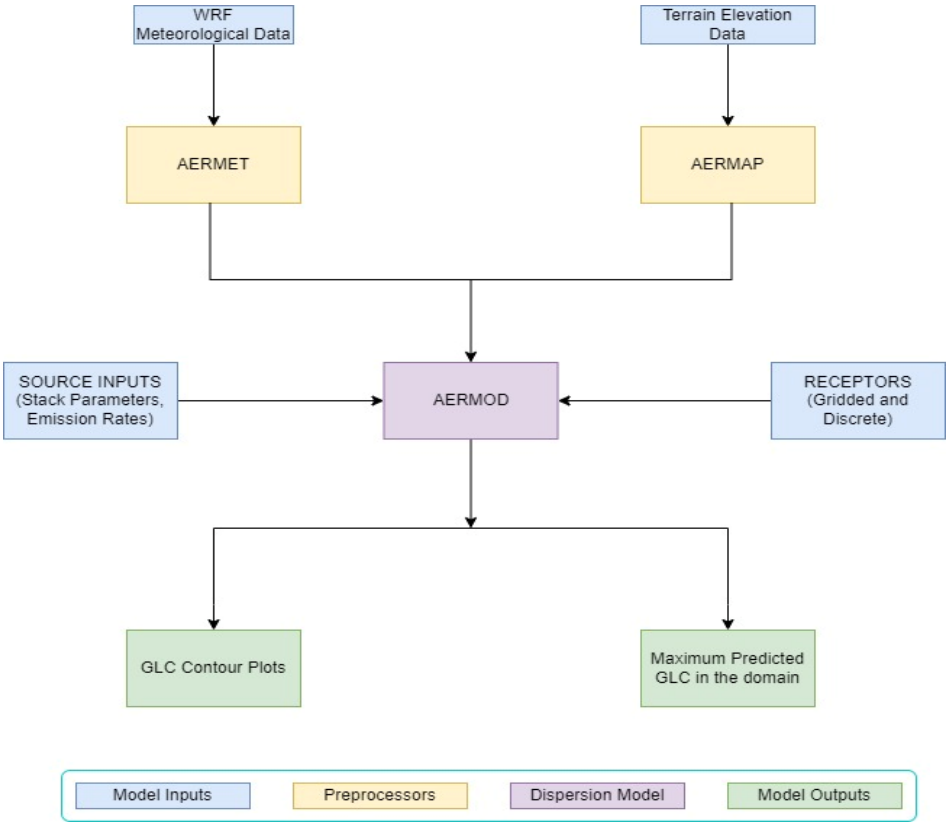


Fig. 2: Data flow in study design.

3 Results and Discussion

3.1 Meteorological

The modeling was undertaken with consecutive three-year meteorological data for 2020–2022. This took into consideration the annual variations in meteorological conditions. The modeling also adopted the maximum hourly vehicular emissions across the three years of meteorological data, ensuring the worst-case short- and long-term concentrations were taken into consideration. Windrose in Fig. 3 below demonstrates that the predominant wind direction in Nairobi is north-easterly, with an annual probability of up to 10.3% and an average wind speed of 5.70–8.80 m/s. Secondary directions were mainly easterly, with an annual probability of 8.2%. The average percentage of calm situations was approximately 4.38%. The windrose for the different seasons during the year are as shown in Fig. 3 below.

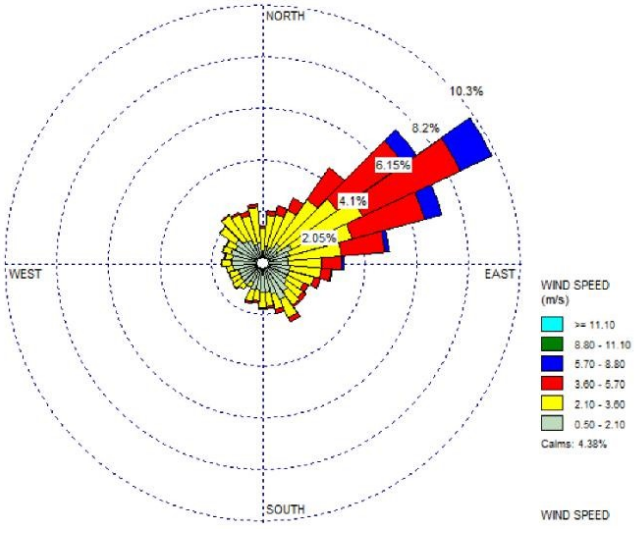


Fig. 3: Windrose Diagram (January 1 2020 to 31 December 2022).

The maximum impact of the emissions is predicted to be mainly in the south-western areas of the corridor, except during July to September, when the emissions fallout areas would be in the north-west of the corridor, which reflected the annual prevailing wind direction of the meteorological data set.

3.2 AERMOD Dispersion Modeling Results

24-hour, 8-hour and annual ground level concentrations of pollutants along the Nairobi Expressway corridor were determined by AERMOD simulations.

3.2.1 Concentration distribution of Carbon Monoxide

The AERMOD simulated that the dispersion of carbon monoxide (CO) concentration ranged from 2 µg/m^3 to 319 µg/m^3. Fig. 4 and 5 below show the dispersion maps and model predictions for maximum 24-hour and annual concentrations of CO on the corridor, which were 319 µg/m^3 and 177 µg/m^3, respectively, at Universal Transverse Mercator (UTM) coordinates 262585.25 m E and 9852845.05 m N.

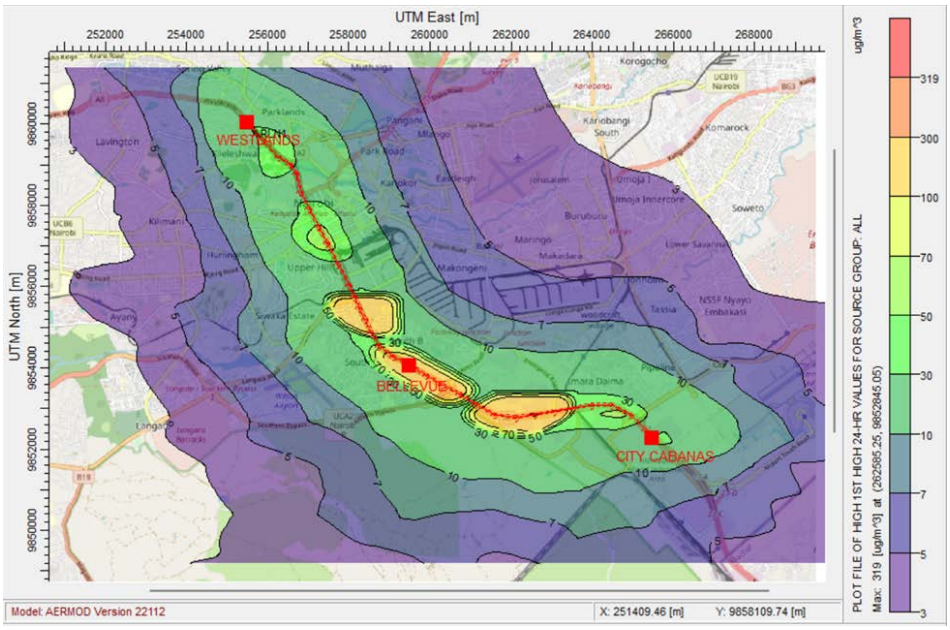


Fig. 4: Maximum Ground Level 8 Hour CO Concentrations.

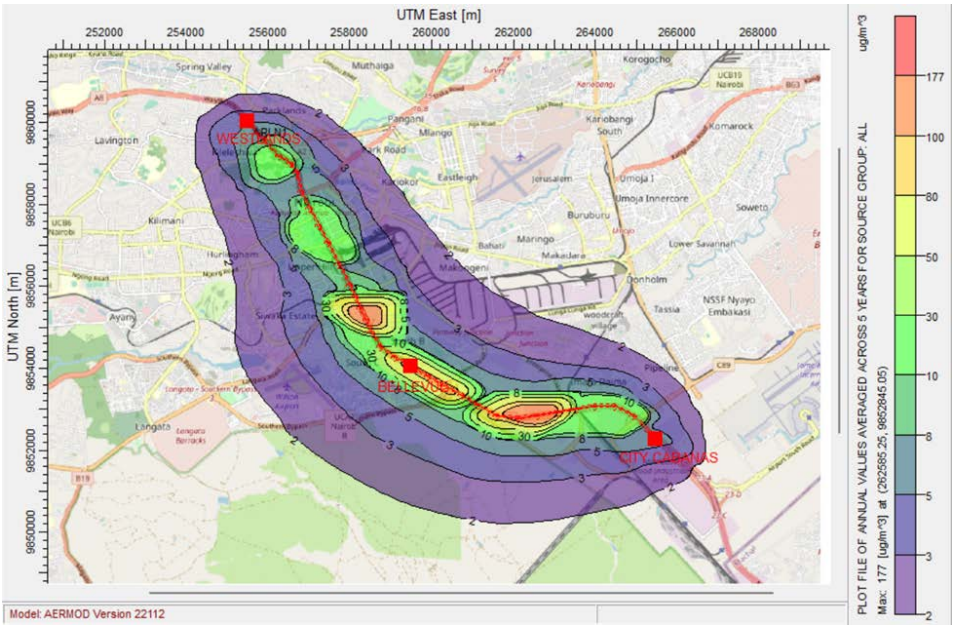


Fig. 5: Maximum Ground Level Annual CO Concentrations.

3.2.2 Concentration distribution of PM_{10}

The dispersion of PM_{10} concentration from the corridor ranged from 0.002 µg/m^3 to 0.405 µg/m^3, according to the AERMOD simulation. The maximum 24-hour and annual PM_{10} concentrations on the corridor were predicted to be 0.405 µg/m^3 and 0.225 µg/m^3 respectively, at Universal Transverse Mercator (UTM) coordinates 262585.25 m E and 9852845.05 m N, as shown in Figs. 6 and 7 below.

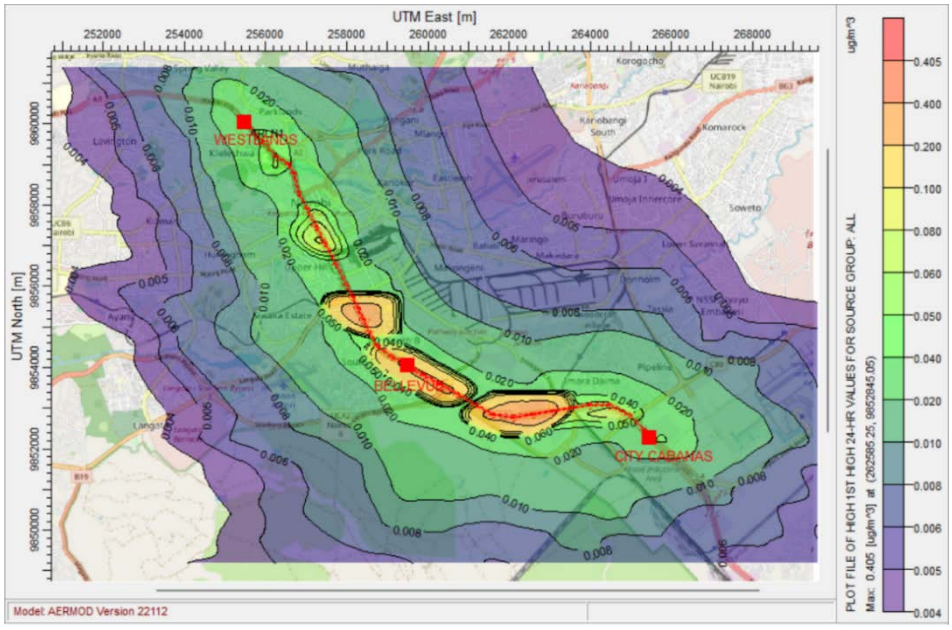


Fig. 6: Maximum Ground Level 24-Hour PM_{10} Concentrations.

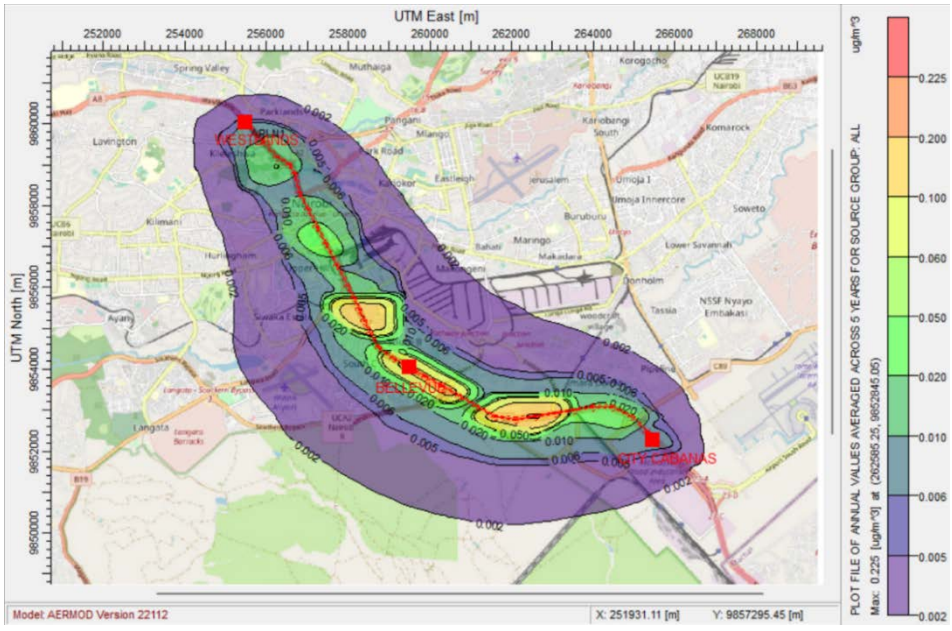


Fig. 7: Maximum Ground Level Annual PM_{10} Concentrations.

3.2.3 Concentration distribution of $PM_{2.5}$

The AERMOD simulated that the dispersion of $PM_{2.5}$ concentrations ranged from 0.002 µg/m^3 to 0.274 µg/m^3. Figs. 8 and 9 below show dispersion maps, and the model predicted maximum 24-hour and annual concentrations of $PM_{2.5}$ on the Nairobi Expressway corridor, which were 0.274 µg/m^3 and 0.152 µg/m^3, respectively, at Universal Transverse Mercator (UTM) coordinates 262585.25 m E and 9852845.05 m N.

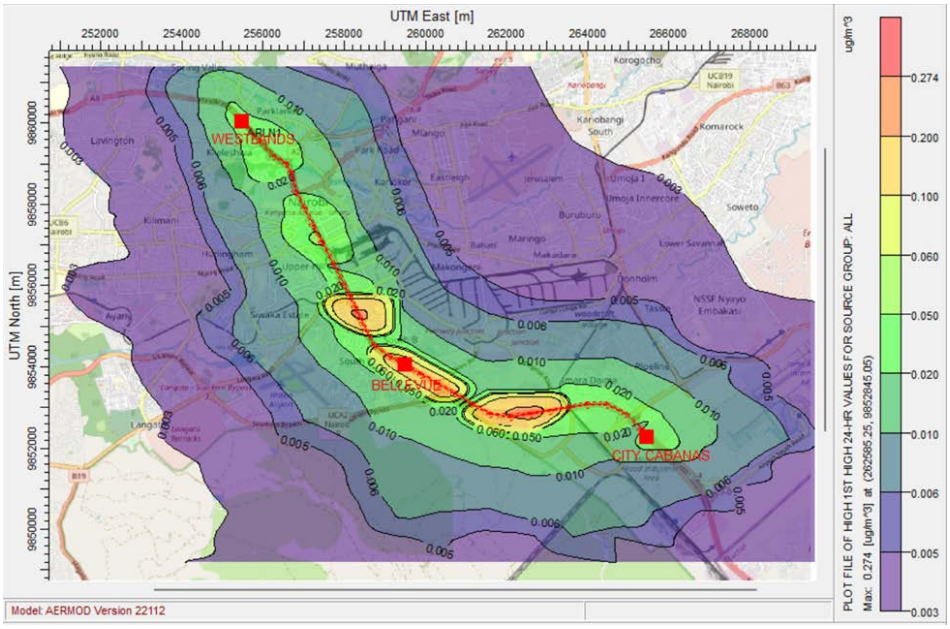


Fig. 8: Maximum Ground Level 24 Hour $PM_{2.5}$ Concentrations.

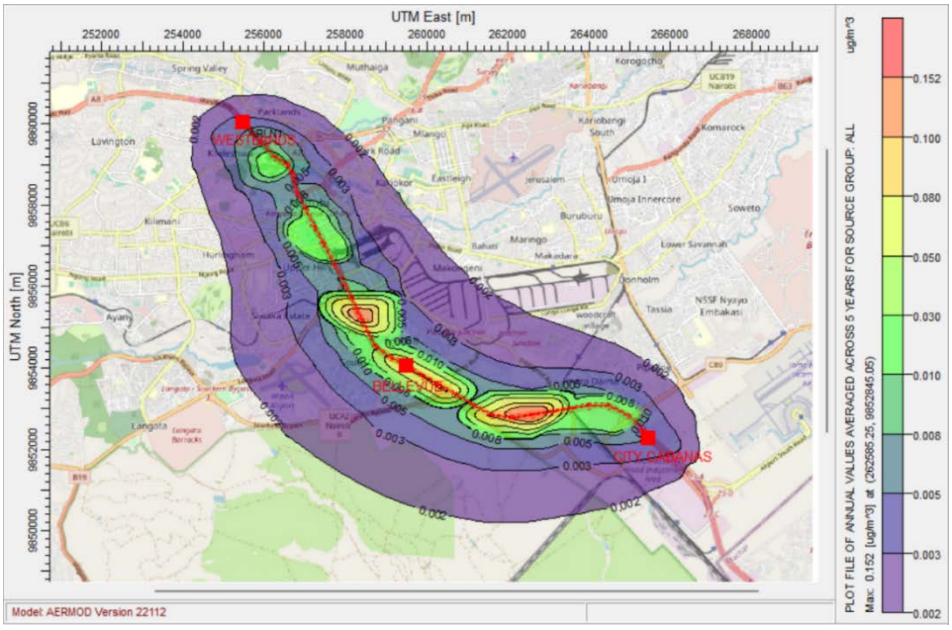


Fig. 9: Maximum Ground Level Annual $PM_{2.5}$ Concentrations.

3.2.4 Concentration distribution of TVOC

The AERMOD predicted that the TVOC concentration dispersion ranged from 0.1 to 20.8 µg/m^3. The corridor's maximum 24-hour and yearly TVOC concentrations were 20.8 µg/m^3 and 11.5 µg/m^3, respectively, at Universal Transverse Mercator (UTM) coordinates 262585.25 m E and 9852845.05 m N, as depicted in Figs. 10 and 11 below.

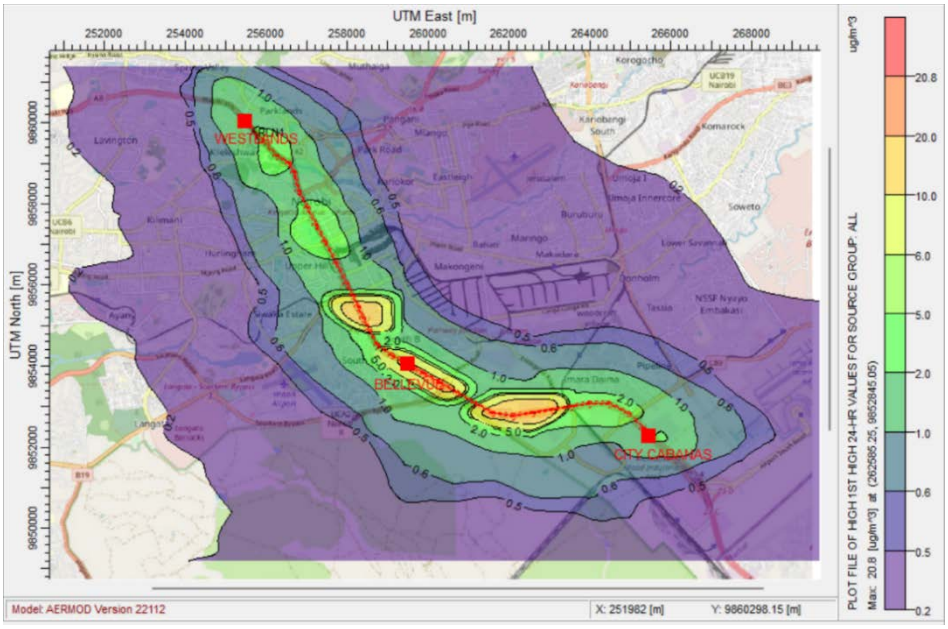


Fig. 10: Maximum Ground Level 24-Hour TVOCs Concentrations.

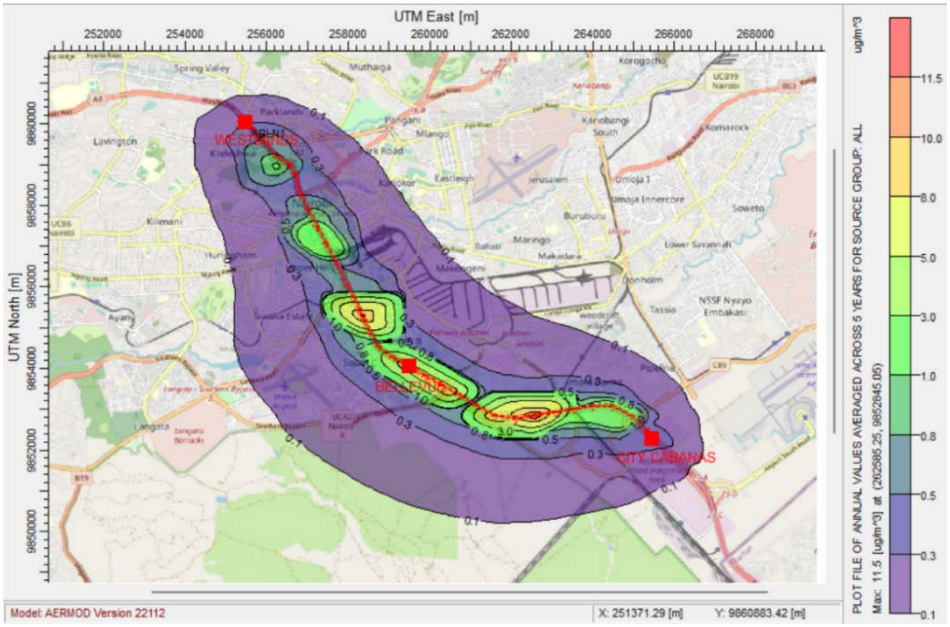


Fig. 11: Maximum Ground Level Annual TVOCs Concentrations.

3.2.5 Concentration distribution of NO_2

The AERMOD predicted that the NO_2 concentration dispersion ranged from 0.2 to 28.2 µg/m^3. The corridor's maximum 24-hour and yearly NO_2 concentrations were 28.2 µg/m^3 and 15.7 µg/m^3, respectively, at Universal Transverse Mercator (UTM) coordinates 262585.25 m E and 9852845.05 m N, as depicted in Figs. 12 and 13 below.

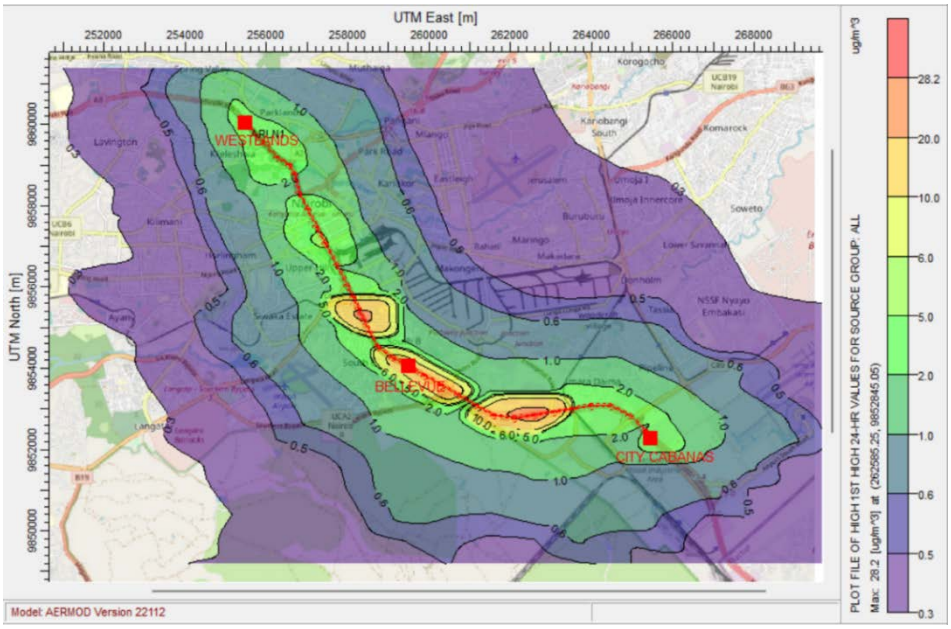


Fig. 12: Maximum Ground Level 24-Hour $N0_2$ Concentrations.

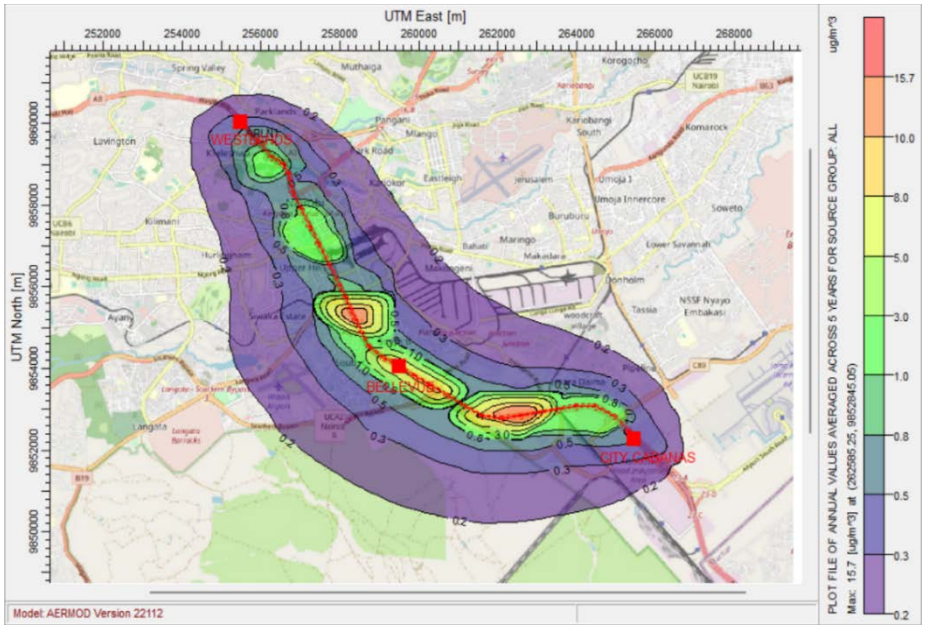


Fig. 13: Maximum Ground Level Annual NO_2 Concentrations.

3.3 Comparison of Modelled and Measured Concentrations

A comparison of the modeled air pollutant concentration results with measured or observed air quality data from monitoring stations was done to check on model accuracy. The maximum modeled concentration of TVOCs for 24-hour duration was 20.8 µg/m^3, whereas the measured maximum average 24-hour concentration was 586.72 µg/m^3. The maximum modeled concentration of PM_{10} for a 24-hour duration was 0.405 µg/m^3, whereas the measured maximum average 24-hour concentration was 24.81 µg/m^3. The maximum modeled concentration of $PM_{2.5}$ for 24-hour duration was 0.274 µg/m^3, however, the measured maximum average hourly and 24-hour concentrations was 24.95 µg/m^3, respectively. The maximum modeled concentration of CO for an 8-hour duration was 319 µg/m^3, whereas the measured maximum average hourly and 8-hour concentration was 580.1483µg/m^3, respectively. The maximum modeled concentration of NO_2 was 28.2 µg/m^3. In all instances, the maximum modelled pollutant concentrations at the identified sensitive receptors were below the NEMA limits. As a percentage of the permissible limits, the average measured 24-hour concentrations of pollutants were 16.5 percent for PM_{10}, 33 percent for $PM_{2.5}$, and 11.6 percent for CO. However, the measured average 24-hour

concentration of TVOCs was found to be exceptionally high, at 97.8% of the NEMA permissible limits. The modeled TVOCs concentration value indicated 3.5 percent contribution of Nairobi expressway traffic to 24-hour average measured TVOCs value while CO contributed to 55 percent of the measured value. The modelled $PM_{2.5}$ and PM_{10} indicated a 1.1 and 1.6 percent contribution of Nairobi expressway traffic to the 24-hour average measured concentration values. The variations in the modelled and measured values indicate the influence of other sources on ambient air quality, such as the other link roads and industries near the expressway corridor. City Cabanas station recorded the maximum concentrations of the emissions in both modelled and measured values which can be attributed to the topography and annual prevailing wind direction of the meteorological data set. The comparison of the maximum modelled concentrations to the Kenya's National Environment Management Authority (NEMA) Air quality Standards [26] is as presented in Table 2.

Table 2: Maximum predicted pollutant concentration compared with Air Quality Limits.

Pollutant	Average Period	Maximum Modelled [µg/m^3]	NEMA Air Quality Limit [µg/m^3]	Maximum Modelled Concentration as % of the Limit
NO_2	24-hour	28.2	**150**	**18.8**
	Annual	15.7	**80**	**19.6**
TVOCs	24-hour	20.8	**600**	**3.5**
	Annual	11.5	**NR**	**-**
PM_{10}	24-hour	0.405	**150**	**0.3**
	Annual	0.225	**70**	**0.3**
$PM_{2.5}$	24-hour	0.274	**75**	**0.4**
	Annual	0.152	**35**	**0.4**
CO	8-hour	319	**5,000**	**6.4**
	Annual	177	**NR**	**-**

*NR – Not Regulated.

4 Conclusion

The emission rates, meteorological data, and terrain data were used in the AERMOD model to estimate $PM_{2.5}$, PM_{10}, NO_2, TVOC, and CO concentrations from vehicular traffic and the spatial dispersion of each pollutant. The concentration values shown on the maps ranged from 0.03 to 0.274 µg/m^3 for $PM_{2.5}$, 0.04 to 0.405 µg/m^3 for PM_{10}, from 0.20 to 20.8 µg/m^3 for TVOC, from 0.2 to 28.2 µg/m^3 for NO_2, and 3 to 319 µg/m^3 for CO. The dispersion of the pollution followed the topography and prevailing wind conditions. Maximum air pollutant concentration values were recorded at 262585.25 m E and 9852845.05 m N. A comparison of the modeled versus the measured air pollutants indicated 3.5 percent contribution of Nairobi expressway traffic to 24-hour average measured TVOCs values while CO contributed to 55 percent of the measured value. The modeled $PM_{2.5}$ and PM_{10} indicated a 1.1 and 1.6 percent contribution of Nairobi expressway traffic to the 24-hour average measured concentration values. A comparison of the measured and maximum modeled air pollutants with NEMA air quality guidelines indicated that the concentration values did not exceed the NEMA permissible limits.. A variation between the modeled and measured values is attributed to the simulation being done for Nairobi Expressway corridor traffic only and not on all the road networks and links joining the road. In addition, other background sources of pollution such as plants and industries were not taken into consideration.

This study therefore provided an estimate of the contribution of Nairobi Expressway corridor traffic to air pollution in Nairobi. The AERMOD dispersion results offer details on the pollutants' spatial distribution throughout the Nairobi highway route. According to the models, traffic on the Nairobi highway contributed to the emissions along the corridor. Future simulations should incorporate all local emission sources, including the entire Nairobi Road network, and thoroughly explore the impacts of seasonal variation on the ambient air quality. This study employed emission factors from the National Pollution Inventory, which are based on studies done on vehicles in different regions; however, in order to provide accurate simulation results that are realistic and representative of the conditions in Kenya, it is crucial that improved emission factors be developed for future studies.

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