MODELLING OF GROUND LEVEL CONCENTRATION OF PARTICULATE MATTER IN MAJOR NIGERIAN UNIVERSITY AIRSHED

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Abstract

Modelling of air pollutants for air quality assessment has been an important landmark achievement by environmentalists especially in areas where on-the-field monitoring is not economical. Models have proven to be cost-efficient and predicts better with different sample sizes. The objective of this study was to model the particulate matter pollutants of a major Nigerian university airshed and to compare of the predicted results with regulatory standards. Dispersion modelling analysis using for line and point sources study of the university airshed was carried out. Prior to the use of the modelling tool, vehicular counts, emission estimation and loads for the two pollution sources was done. The predictions revealed that concentration levels of PMs to emission source and receptor environments for the line source study were extremely high due to factors such as emission height and meteorological conditions of the university. The predicted concentrations from the point source were moderate and the reason is due to the emission height (stack height), wind speed and direction. Other contributing sources could be as a result of biomass burning, bush burning and pollutant transport. This study will be a bedrock for institutional-based air quality assessment that checkmate the anthropogenic contribution to deteriorating ambient air.

Keywords: Particulate Matter, Concentration, University, Dispersion Modeling

1. Introduction

There has been significant rise in air pollution cases in developing countries in the world due to factors such as urbanization, industrialization, pollution generation in places of work, residences and transportation (Pereira *et al.,* 2004, Adeniran *et al.,* 2017, dos Santos Cerqueira *et al.,* 2019, Nair *et al.,* 2020). Emissions from traffic or vehicular transport contributes more to the ground-level air pollution (Kumar *et al.,* 2017).

Pollution from air has been one of the major concerns for the World Health Organization (WHO) due to the severe health concerns and environmental impacts affecting all living and non-living organisms (Oudin *et al.,* 2019) and more focus has been on the urban centers due to the high level of pollutions found in this type of environment (White *et al.,* 2019). In addition, air pollutants dispersion is easy while its retention is somewhat difficult because emission from different sources are multifaceted and is a function of space and time (dos Santos Cerqueira *et al.,* 2019). Contributing factors to an aggravated urban air pollution are the mass movement of rural population and regional transport of pollutants – the change in the demographical settings of a particular location will affect both the region, hence the global environment and regional transport have been reported to be major air pollution sources (Kumar *et al.,* 2017, Yin and Zhang 2020).

The particulate matter with aerodynamic diameter less than 10 µm (PM_{10}) may also include both coarse and fine particles ($PM_{2.5}$ and $PM_{1.0}$) (Amoatey *et al.,* 2019, White *et al.,* 2019) and toxic trace elements such as chromium (Cr), cadmium (Cd), zinc (Zn), arsenic (As), and nickel (Ni) (Khaniabadi *et al.,* 2018). Reported health consequences of air pollutants such as particulate matter include hazards that may affect the central nervous system (Oudin *et al.,* 2019); increase in morbidity and mortality (Sonibare *et al.,* 2019, White *et al.,* 2019); lung cancer, heart attacks, dementia, premature death (Khaniabadi *et al.,* 2018); and cardiovascular and respiratory diseases (Elford and Adams 2019).

Transport or vehicular movements is a very good example of unregulated man-made activities (Nair *et al.,* 2020) and are major source of pollutant emission at ground level in the environment (Kumar *et al.,* 2017). Transportation system in schools are used to convey humans (staff, students, shop owners) and goods. This has received less attention in air pollution studies as this type of commute-related dosage occurs during movement from one fixed locations to another (Elford and Adams 2019). Since it involves an active transportation system, the dispersion rate, terrain characteristics and mode of travel requires a suitable approach for proper representation (Elford and Adams 2019).

The use of dispersion modelling software has made it possible to predict the PM concentration level in the emission source and receptor environment. Researchers have used different dispersion modelling software for air pollution studies such as AERMOD, CALPUFF, ADMS, ISC3, SCREEN3 (Kalhor and

Bajoghli 2017, Kumar *et al.,* 2017, Khaniabadi *et al.,* 2018, Amoatey *et al.,* 2019, dos Santos Cerqueira *et al.,* 2019, Sonibare *et al.,* 2019). The AERMOD view modelling system was approved by EPA (Environmental Protection Agency) for air pollution studies for about 50 km radius from emission source and its development was based on the Gaussian plume model which can be used for different terrain types (simple and complex) and different plume direction (horizontal and vertical) (Amoatey *et al.,* 2019, Elford and Adams 2019).

Several other studies have carried out the PM dispersion modelling studies using ISC-AERMOD software. AERMOD has also been used in dispersion study of TSP in a Nigeria Highway (Adebayo *et al.,* 2016), to study PM exhaust emission from vehicles in Lithuania (Vaitiekūnas and Banaityte 2007), to investigate point and line sources emission of $PM_{2.5}$ and other gaseous pollutants in four locations in Nova Scotia, Canada (Gibson *et al.,* 2013), to predict air pollutants concentration ar ground level including PMs in Nigeria thermal power plants (Adesanmi *et al.,* 2016), to assess air quality and model pollutants including PM_{10} emission from a Nigerian cement plant (Adeniran *et al.,* 2018), and to study the dispersion of PM_{10} over the city of Pune, in India (Kesarkar *et al.,* 2007).

Nigeria universities are similar to mini-urban settings in terms of activities which spans across buying and selling of goods and services, vehicular movements, stationary supplies and services, staffs and student's conveyance via mobile transport and daily running of the administrative and academic work using either electric power supplies or backup generators. In the university environment, the two major anthropogenic sources mostly present are mobile (vehicular emission) and stationary (backup generators). Electricity power also contributes as the plans on more power generation has shifted towards the use of thermal plants which also emits gases that pollutes the environment (Sonibare 2010). Despite the fact that previous studies were conducted on stationary and mobile sources using AERMOD dispersion modelling tool and ground level sampling of PMs, these findings do not represent the institutional based airshed quality. Therefore, this study aim to carry out particulate matter modelling of a major Nigerian university airshed with AERMOD software.

2 Materials and methods

2.1 Description of the study location

The University of Ilorin is in the North Central geopolitical region of Nigeria on latitude 8.4799°N and longitude 4.5418°E covering an approximate land mass of 5,000 hectare. The university has a total number 56,718 students and a staff strength of 4,376 comprising of teaching and non-teaching staffs for the 2017/2018 academic session.

Out of these population, a large proportion of the students and staff live outside the university campus and are either conveyed to the institution through commercial transport or privately-owned vehicles that contributes to continuous emission. More so, there are hostels for students and residential staff quarters in the university. However, the locations of some of these facilities has warranted the use of intra-university transport (tricycles) and private vehicles by staffs.

It is important to note that business men/women that offers commercial services of buying and selling were not accounted for in the stated university's population. However, their contribution to air quality deterioration was accounted for in the vehicular count for traffic inflow into the university. It was assumed that the university open between 0600 hours and 0700 hours while the closing is around 2200 hours and 2300 hours every day including weekends. The main entrance and exit which allow passage of commuters in and out of the university are always busy during the early hours of the day, 0700 and 0900 hours and as well during the peak closing period of 1500 hours to 1730 hours. Other instances of heavy and congested traffic are experienced during examination period, matriculation and convocation ceremonies.

The study investigated the six (6) intra-university roads including the main road from the town as line sources and the eleven (11) generator houses in the university as point source.

2.2 Emission Estimation

In the estimation of particulate matter in the university community, the emission estimation equation was used. However, prior to the estimation, vehicular count (traffic inflow and outflow) through the main gate of the university was done to have an idea of the average number of vehicles for 1h, 1 month and a year. Other road connections in the university premises was considered and the vehicular count was also done to account for the total emission in the university. Also, considering the fact that, different vehicle types uses different fuels (diesel and petrol), the vehicular count accounted for this scenario and the vehicles were categorized as cars, omnibuses, big buses, trucks and tricycles.

2.2.1 Emission estimation from anthropogenic sources

In this study, anthropogenic sources considered are mobile and stationary emission. Therefore, emission factors methodology was needed to calculate the emission estimation and rate respectively. Different vehicle types were considered hence the fuel type and engine capacity differs. This leads to the use of different emission factors for vehicle types and point source emission, i.e. the backup generators. Emission

factor AP-42 of the United States Environmental Protection Agency (USEPA) was used.
Emission estimation is represented by the relation that combines activity rate, the emission factors and emission reduction efficiency. This is given as:

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right) \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where E the emission estimation of pollutant i,
EF the emission factor (g/km)
ER the emission reduction efficiency (percent)
A the activity rate, which is also given as;

$$A = \frac{distance}{vehicle}\left({km}/{veh.}\right) \times traffic\ volume\ \left(\frac{veh.}{hr}\right) \ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$E_i\left(\frac{g}{hr}\right) = \frac{distance}{vehicle}\left({km}/{veh.}\right) \times emission\ factor\ \left(\frac{g}{km}\right) \times traffic\ volume\ \left(\frac{ve}{hr}\right) \quad (3)$$

The activity rate was represented here by the combination of the traffic volume (vehicle per hour) and distance travelled by each vehicle (kilometer per vehicle).

Table 1: Emission factors for mobile source (vehicle)

	Emission factor (g/km)			
Vehicle Type	PM_{10}	$PM_{2.5}$	BC	OC
Cars	0.0064	0.0059	0.00131	0.00497
Omnibuses	0.0104	0.00752	0.00292	0.00634
Big buses	0.00994	0.0092	0.0023	0.00746
Trucks	0.2561	0.248	0.121	0.130
Tricycles	0.02374	0.219	0.00435	0.002

Source: (UNEP/World Bank 1996, Argonne National Laboratory 2013, USEPA 2015)

Table 2: Emission factor for stationary source (Backup generators)

Pollutants	Emission Factor (kg/kW-hr) (Power output)	Emission Factor kg/m^3 (Fuel input)
PM_{10}	0.0013	5.1
$PM_{2.5}$	0.0013	5.0

Source: (USEPA 1995)

Table 1 shows the emission factors for vehicle emissions was obtained from different sources (Argonne National Laboratory, UNEP and USEPA) respectively. Table 2 represents emission factors from USEPA for diesel-powered generators based on fuel consumption and power rating.

2.3 ISC-AERMOD view

ISC-AERMOD view dispersion modeling tool was used in this assessment studies. The modeling tool is a powerful but simple software that include the three most popular US EPA models (AERMOD, ISCST3, and ISC-PRIME) into a single model. For AERMOD functionality, it makes use of pathways that contains runstream files. The pathways are control pathways (CO), source pathways (SO), receptor pathways (RE), meteorology pathways (ME), terrain grid pathway (TG) and output ways (OU) (Adeniran *et al.,* 2018).

2.3.1 Receptor location

The university is situated close to densely populated area of the city with communities and rural settlements that share borders with it. The immediate and far distant environments were taken into consideration as the receptors to the air pollutants from the University. In order to have a significant and well quantified receptor, 50km radius within the University community was used.

2.3.2 Meteorological data

An important input parameter of the modelling software (ISC-AERMOD) is the meteorological data. Upward wind data of the University community were obtained from the Department of Physics, University of Ilorin. The data obtained include temperature, wind speed, wind direction, relative humidity, sun intensity, air pressure, and dew point temperature. The data were incorporated in a format needed for the modelling software.

2.4 Emission data

In this study, the emission rates estimation was divided into two: a line source study (six (6) roads) for emissions of particulate matter ($PM_{2.5}$, PM_{10}, OC and BC) from vehicles; and a point source study which investigated the emissions from backup generators (BUGs) for PM_{10}, and $PM_{2.5}$.

2.4.1 Line sources

In the line source study, the main road (LS1) with five (5) intra-university road within the university perimeter. From Table 3, the vehicle count is presented for the line sources study.

Table 3 Statistical data for vehicular count for line sources

	Vehicular count (vehicle/hr.)					
Vehicle type	LS1	RD1	RD2	RD3	RD4	RD5
Cars	593	336	144	144	378	144
Omnibuses	324	564	6	0	0	0
Big buses	48	72	0	6	12	6
Trucks	10	0	0	12	0	12
Tricycles	6	6	306	180	660	174

From the traffic volume data, it is evident that on an average, 981 vehicles passed through the main gate into the university community through road LS1, 978 vehicles plied the road RD1, 456 vehicles passed through road RD2, 342 vehicles passed through RD3, 1050 vehicles passed through road RD4 and 336 vehicles passed through road RD5 for one hour count. The counting process was carried out during weekdays and weekends while considering the busiest hours of 0800 hours to 0900 hours and also 1500 hours to 1600 hours which represent peak opening and closing hour of normal activities for both staff and students.

Table 4 ISC-AERMOD view line sources input parameters

Parameters	Values				
	X-a (m)	Y-a (m)	X-b (m)	Y (b)	Road Distance (km)
LS1	1430.89	4292.63	4759.12	4195.77	5.41
RD1	5014.23	2916.91	5055.15	2906.21	0.73
RD2	5010.54	2873.45	4978.83	2936.02	0.45
RD3	5044.25	2885.64	5063.97	3079.36	1.87
RD4	5072.92	2869.4	5063.97	3079.36	1.41
RD5	4978.83	2936.02	5039.89	2924.52	0.5
Car Width (m)	1.4				
Road Width (m)	4.0				
Emission Height (m)	0.4				
Dual Road Width (m)	7.3				
Velocity (m/s)	3.4				
Anemometer Height (m)	10.0				

Table 4 shows ISC-AERMOD view line source input parameters for the six (6) road of the University community. The input data include the x and y coordinates for the road's start point to end point, car width, emission height, road width (dual and single), velocity, anemometer height and road distance. Car width and emission height was assumed to be the same for vehicle parameters.

2.4.2 Point source

In the point source determination, the study makes use of emission from backup generators (BUGs) used in the University community as a stationary/point source. Emission estimation and rate for point source was estimated using equation (1), the activity rate (fuel consumption, m^3/yr.) for each generator and emission factor was used. Table 5 is the statistical data obtained for the fuel consumption for each backup generator for the 2016/2017 academic session.

Table 5: Fuel usage of the University Backup Generator

Generator location	Fuel consumption (m^3/yr.)
VC Lodge (GH1)	10.5
College of Health Science (COHS) (GH2)	88.0
Block 3 (GH3)	44.0

Central Power Station (CPS) (GH4)	44.0
Water Treatment Plant (WTP) (GH5)	5.5
Senate Building (SB) (GH6)	22.0
Senior Staff Quarters (SSQ) (GH7)	5.5
Central Research Laboratory (CRL) (GH8)	8.5
Multipurpose Hall (MH) (GH9)	4.5
School of Preliminary Studies (SPS) (GH10)	2.5
Veterinary Teaching Hospital (VTHS) (GH11)	5.5

The generator house with high fuel consumption are presented as follow in descending order; COHS (88 m^3/yr), Block 3 and CPS (44 m^3/yr), SB (22 m^3/yr), VC lodge (10.5 m^3/yr), CRL (8.5 m^3/yr), WTP, SSQ, and VTHS (5.5 m^3/yr), MH (4.5 m^3/yr) and SPS (2.5 m^3/yr).

Table 6 ISC-AERMOD Point Source Input Data

Parameter	Values
Rural or Urban	Urban
Terrain height (Elevated/Flow)	Elevation
Base Elevation (m)	2.0
Release Height (m)	4.0
Emission Rate (g/s)	-
Gas Exit Temperature (^{0}C)	520
Stack Inside Diameter (m)	0.025
Gas Exit Velocity (m/s)	1.5
Gas Exit Flowrate (L/hr.)	3.2

Table 6 shows the point source input parameters for the eleven (11) generator houses in the University community which include settlement specifications (rural/urban), terrain characteristics (elevated/flow), base elevation, gas exit temperature, release height, gas exit velocity, stack inside diameter and gas exit flowrate. Assumptions were made that the base height, gas exit temperature, release height, gas exit velocity and flowrate are the same for all backup generators (BUGs) irrespective of the fuel consumption and capacity.

3. Results and discussions

Figures 1 show the map of the university for the domain study. The area is characterized by vast vegetation cover that spans from the university main entrance to the north, south, and eastern part of the location. Other characteristics include high terrains with hills and a river that flows from the southern part of the university towards the north-west region. The results obtained were discussed in four parts: the emission loads for line source, emission load for point source, dispersion modelling for line source and for point source emissions.

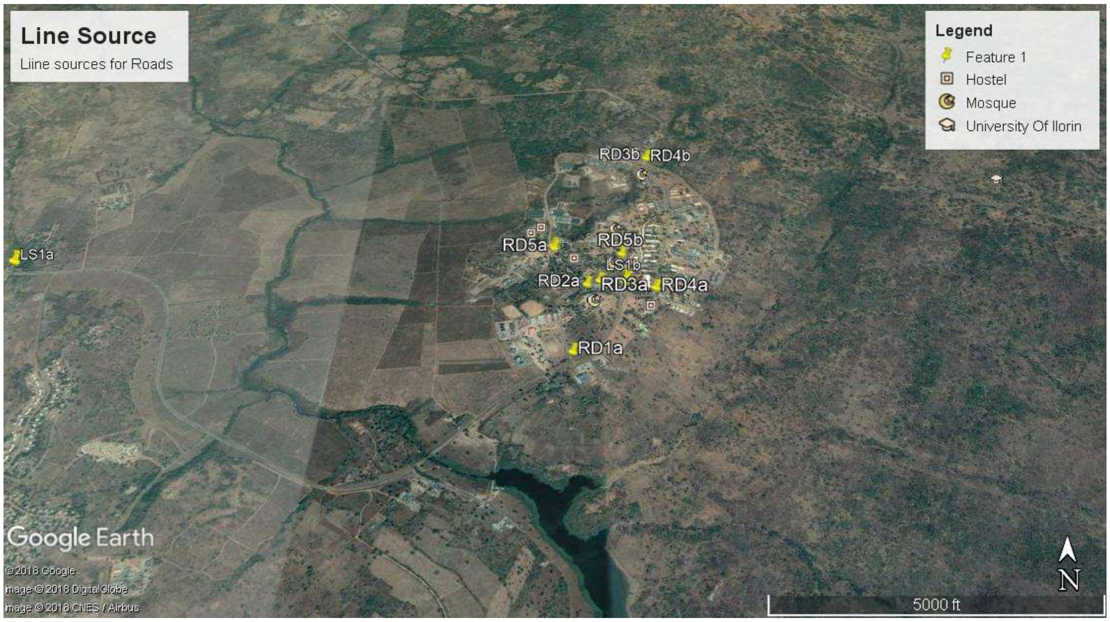

Figure 1: Map of the University for the domain study (line source).

3.1 Emission Estimation

3.1.1 Emission load for line source

Emission load for the line source include emission study from vehicles for six (6) intra-university roads tagged as LS1, RD1, RD2, RD3, RD4, and RD5. The particulate matter pollutants studied are PM_{10}, $PM_{2.5}$, BC and OC.

In order to account for the particulate matter load in the airshed as a result of vehicular movements activities, the PMs considered were PM_{10}, $PM_{2.5}$, BC and OC. Figure 4 shows the statistical representation of the emission load for particulate matters in the domain study. For PM_{10}, the emission load was in the following decreasing order, LS1 with 0.33, RD4 with 0.15, RD3 with 0.09, RD1 with 0.04, RD2 and RD5 with 0.02 tonnes/annum. For $PM_{2.5}$, the emission load pattern has a deviation from PM_{10} with RD4 having 1.21 tonnes/annum, followed by RD3 with 0.47 tonnes/annum, then LS1 with 0.33 tonnes/annum, RD2 with 0.18 tonnes/annum, RD5 with 0.12 tonnes/annum and RD1 with the lowest $PM_{2.5}$ load of 0.03 tonnes/annum. BC emission load estimates shows that LS1 has the highest BC emission followed by RD3, RD4, RD1, RD5 and RD2 with 0.10, 0.03, 0.03, 0.01, 0.01 and 0.004 tonnes/annum respectively. Organic carbon (OC) in the line source load showed that LS1 topped the emission sequence with 0.22 tonnes/annum, followed by RD4 with 0.12 tonnes/annum, RD3 with 0.063 tonnes/annum, RD1 with 0.025 tonnes/annum, while RD2 and RD5 both has 0.017 tonnes/annum each.

The highest PM load was $PM_{2.5}$ with a total load of 2.34 tonnes/annum, followed by PM_{10} with 0.65 tonnes/annum, OC has a total emission load of 0.46 tonnes/annum and lastly, BC with an emission load of 0.17 tonnes/annum. The predominance of $PM_{2.5}$ in the emission estimation maybe largely due to the increased traffic volume of cars and tricycles in some of the road sections. Road section RD4 for instance, has the highest tricycles and car count and is characterized with heavy commercial activities and two university generator houses. Other sources of the particulate could be from these other sources and also dust resuspensions from road side movements by students, staffs and brake and tyre wears from vehicles (Nagpure *et al.,* 2016). The presence of black carbon and organic carbon as part of the components of PMs has been reported by several authors (EEA 2016, Zavala *et al.,* 2017) and the emissions has been associated with both petrol and diesel-fueled vehicles. The health effect of PM is of combined effect due to the compositions (BC and OC components). It has on outdoor and indoor exposure which could lead to respiratory and cardiovascular diseases (Tuddenham and Roussel 2013). The emission of BC in the ground level of the receptor environment poses a global warming threat to the earth as BC absorbs sunlight and heat the air thereby warming the atmosphere via radiation and conduction.

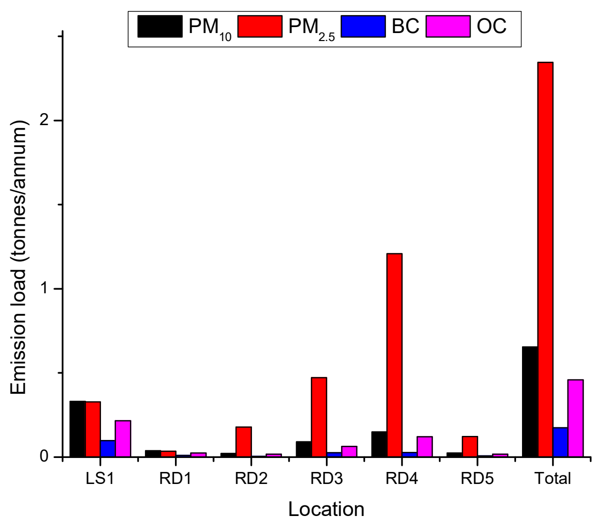

Figure 4: Emission load for particulate matter (line source)

3.1.2 Emission estimation for point source

Emission load estimation for the point source study was carried out for stationary emissions from backup generators in the university community. Eleven (11) generator houses were considered here and the particulate matter pollutants estimated for emission into the environment are $PM_{2.5}$ and PM_{10}.

$PM_{2.5}$ and PM_{10} were estimated to quantify the emission load from stationary source in the university study domain. In Figure 5, the highest values are 0.449 tonnes/annum and 0.440 tonnes/annum while the lowest values are 0.013 tonnes/annum for $PM_{2.5}$ and PM_{10} respectively. Total PMs load are 1.23 and 1.20 tonnes/annum for PM_{10} and $PM_{2.5}$ respectively.

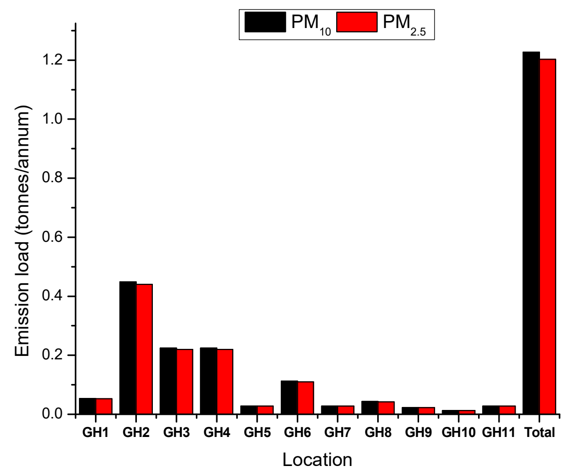

Figure 5: Emission load for PMs from point source.

3.2 Line source dispersion modelling

For the line source domain study, Table 7 (a – c) lists the emission rate (in g/s) of PM_{10}, $PM_{2.5}$, and BC for LS1, RD1, RD2, RD3, RD4 and RD5 respectively. The dispersion modelling of PM_{10}, $PM_{2.5}$, and BC was predicted using the ISC-AERMOD view for 1-hr, 8-hr, 24-hr and annual average and the isopleths will be discussed in the next section.

Table 7a Emission rate for line source study in road LS1 and RD1.

Vehicle Type	Emission rate (g/s)					
	LS1			RD1		
	PM_{10}	$PM_{2.5}$	BC	PM_{10}	$PM_{2.5}$	BC
Cars	5.7E-03	5.3E-03	1.2E-03	0.000436	0.000402	0.00009
Omnibuses	5.1E-03	3.7E-03	1.4E-03	0.001189	0.00086	0.00033
Big buses	7.1E-04	6.6E-04	1.7E-04	0.000145	0.000134	0.00003
Trucks	4.0E-03	3.9E-03	1.9E-03	0	0	0
Tricycles	2.3E-04	2.1E-03	4.2E-05	2.89E-05	0.000266	0.00001

Table 7b Emission rate for line source study in road RD2 and RD3.

Vehicle Type	Emission rate (g/s)					
	RD2			RD3		
	PM_{10}	$PM_{2.5}$	BC	PM_{10}	$PM_{2.5}$	BC
Cars	0.000115	0.000106	0.000023	0.000479	0.000441	0.0000976
Omnibuses	7.8E-06	5.64E-06	0.000002	0	0	0
Big buses	0	0	0	3.1E-05	2.87E-05	0.0000072
Trucks	0	0	0	0.001596	0.001548	0.0007511
Tricycles	0.000908	0.008369	0.000166	0.00222	0.020458	0.0004068

Table 7c Emission rate for line source study in road RD4 and RD5.

Vehicle Type	Emission rate (g/s)					
	RD4			RD5		
	PM_{10}	$PM_{2.5}$	BC	PM_{10}	$PM_{2.5}$	BC

Cars	0.000948	0.000873	0.000193205	0.000128	0.000118	0.0000261
Omnibuses	0	0	0	0	0	0
Big buses	4.67E-05	4.32E-05	0.00001081	8.28E-06	7.67E-06	1.91667E-06
Trucks	0	0	0	0.000427	0.000414	0.000200833
Tricycles	0.006137	0.05656	0.001124734	0.000574	0.005288	0.000105149

3.2.1 Isopleths for line source

Figure 6 (a–f) represents the ground level concentration in the isopleths for 24-hr PM_{10} concentration in LS1, 24-hr $PM_{2.5}$ concentration in RD1, annual PM_{10} concentration in RD2, annual $PM_{2.5}$ concentration in RD3, 24-hr BC concentration in RD4 and annual BC concentration in RD5 respectively. Other isopleths of 1-hr, 8-hr and 24-hr averaging concentrations for the pollutants are presented in the supplementary data. The maximum concentration obtained from the dispersion modeling analysis were compared with regulatory standards of United States Environmental Protection Agency (USEPA), World Bank (WB), Federal Ministry of Environment (FMEnv) and the World Health Organization (WHO) in Table 8. The table presents particulate matter concentration from the line source comprising of the six (6) roads in the university domain study.

In the line source study for PMs emission, PM_{10} emission at the 24-hr averaging level ranged from 10 to 203 times the USEPA limit of 150 $\mu g/m^3$, $PM_{2.5}$ emission has a range of multiples of 100 to 5417.1 times the USEPA limit of 35 $\mu g/m^3$, the annual PM emission from the six (6) roads have a range of 5 to 325 times of the 20 $\mu g/m^3$ from USEPA and 53.3 to 2867 times of the USEPA value of 15 $\mu g/m^3$ for PM_{10} and $PM_{2.5}$, respectively by using the limits as presented in Table 8. From the presented results, all guideline values exceeded allowable limits as predicted by the modelling analysis which could be attributed to the emission height of the vehicle exhausts when compared to stack height of the generators and the prevailing microclimatic condition; this poses an ambient air degradation threat to the university and receptors communities.

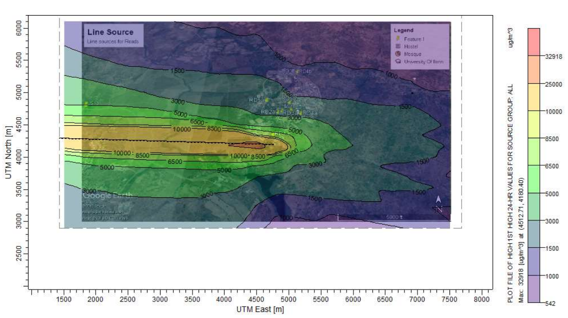

Figure 6a: 24-hr PM_{10} Isopleth in LS1

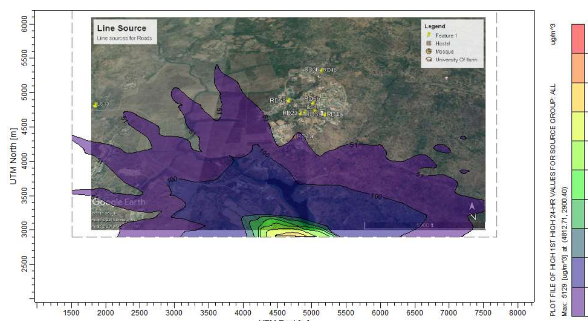

Figure 6b: 24-hr $PM_{2.5}$ Isopleth in RD1

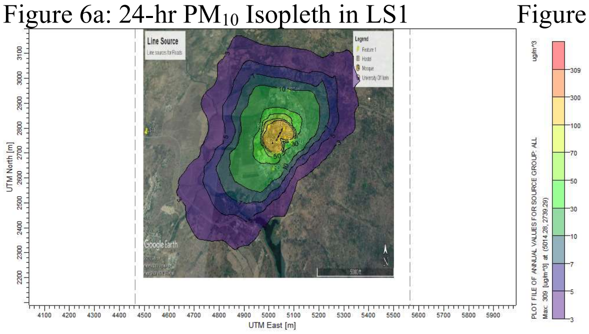

Figure 6c: Annual PM_{10} Isopleth in RD2

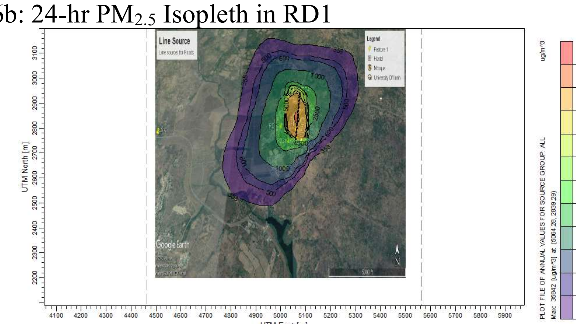

Figure 6d: Annual $PM_{2.5}$ Isopleth in RD3

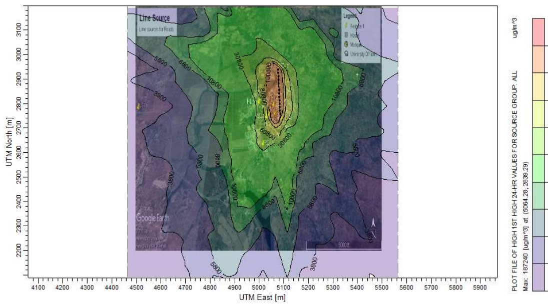

Figure 6e: 24-hr BC Isopleth in RD4

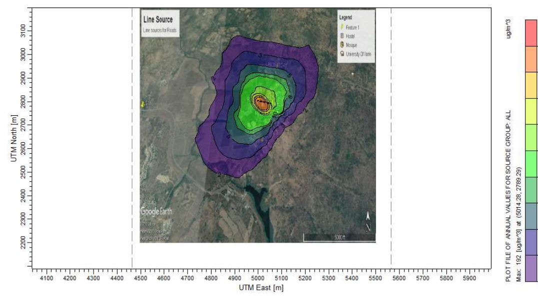

Figure 6f: Annual BC Isopleth in RD5

3.3 Point source dispersion modelling

For the point source domain study, Table 13 lists the emission rate (g/s) of PM_{10}, and $PM_{2.5}$ for the eleven generator houses (GH1, GH2, GH3, GH4, GH5, GH6, GH7, GH8, GH9, GH10 and GH11) respectively. The dispersion modelling of these pollutants was predicted using the ISC-AERMOD view for 1-hr, 8-hr, 24-hr and annual average and the isopleths detailing the ground level concentrations will be discussed in the next section.

Table 8 Maximum concentration from vehicular emission to the university airshed.

Location	Concentration ($\mu g/m^3$) 24-hr		Annual	
	PM_{10} (E+04)	$PM_{2.5}$ (E+04)	PM_{10} (E+03)	$PM_{2.5}$ (E+03)
LS1	2.5 (166.7 times)	3.27 (934.3 times)	5.0 (250 times)	7.23 (482 times)
RD1	0.4 (26.7 times)	0.35 (100 times)	1.0 (50 times)	0.8 (53.3 times)
RD2	0.15 (10 times)	1.0 (285.7 times)	0.1 (5 times)	1.0 (67 times)
RD3	3.04 (203 times)	15.78 (4508.6 times)	6.50 (325 times)	30 (2000 times)
RD4	2.35 (156.7 times)	18.96 (5417.1 times)	5.34 (267 times)	43 (2867 times)
RD5	0.299 (20 times)	1.563 (447 times)	0.653 (33 times)	3.41 (227.3 times)
Limit	**150[a]** **50[b]**	**35[a]** **25[b]**	**20[b]**	**15[a]** **10[b]**

[a] USEPA, [b] WHO

Table 9 Emission rate for point/stationary source.

Generator House	Emission rate (g/s) PM_{10}	$PM_{2.5}$
GH1	0.0017	0.0017
GH2	0.0142	0.0140
GH3	0.0071	0.0070
GH4	0.0071	0.0070
GH5	0.00089	0.00087
GH6	0.0036	0.0035
GH7	0.00089	0.00087
GH8	0.0014	0.0014
GH9	0.00073	0.00071
GH10	0.0004	0.00040
GH11	0.0009	0.00087

3.3.1 Isopleths for point source

Figure 7a – d shows the ground level concentration in the isopleths for 24-hr PM_{10} concentration, annual PM_{10} concentration, 24-hr $PM_{2.5}$ concentration and annual $PM_{2.5}$ concentration respectively. Other isopleths of different averaging concentrations for the PM, are presented in the supplementary data. The maximum concentration of the point source emission obtained from the dispersion modeling analysis were compared with regulatory standards of USEPA and WHO in Table 10. The table presents the particulate matter concentration from the point source comprising of the eleven (11) backup generators in the university domain study.

As observed in the isopleths in the Figure 7 (a - d), the maximum ground level particulate matter (PM_{10} and $PM_{2.5}$) concentration for 24-hr are 5.04 and 4934 μg/m^3 respectively. PM_{10} value is 3.4 % of 150 μg/m^3 by USEPA and 10.1 % of 50 μg/m^3 by WHO, while $PM_{2.5}$ concentration is in 141 folds of 35 μg/m^3 by USEPA and 197.4 times the 25 μg/m^3 limit by WHO. PM_{10} annual concentration does not exceed the guideline limit, the value was 0.99 μg/m^3 and is 5 % of 20 μg/m^3 by WHO; while $PM_{2.5}$ concentration of 985.9 μg/m^3 also exceeds the allowable limits at 66 times of the 15 μg/m^3 by USEPA and 98.6 times of the 10 μg/m^3 by WHO, respectively.

Generally, it was observed that the concentration of these pollutants is high at emission source and due to dispersion by the prevailing meteorological parameters, the concentrations are reducing away from source and towards the receptor environment. Low values of pollutants predicted do not exceed allowable limits, this may be due to emission stack height of these backup generators.

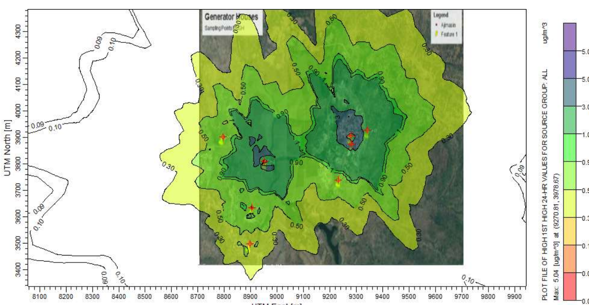

Figure 7a: 24-hr PM_{10} Isopleth

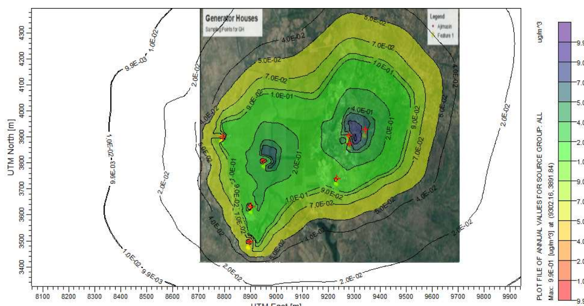

Figure 7b; Annual PM_{10} Isopleth

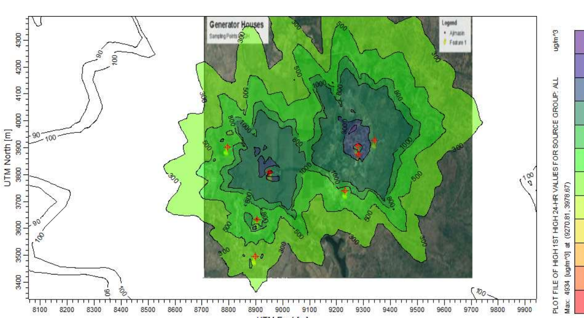

Figure 7c: 24-hr $PM_{2.5}$ Isopleth

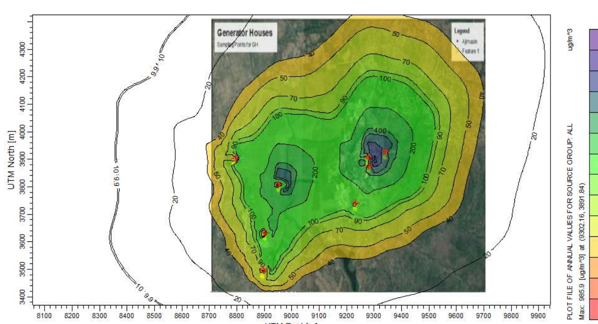

Figure 7d:Annual $PM_{2.5}$ Isopleth

Table 10Maximum concentration from generator emission to the university airshed.

Domain study	Concentration (μg/m^3)			
	24-hr		Annual	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Point source	5.04	4934	0.99	985.9
	3.4^a %	141^a folds	5^b %	66^a folds
	10.1^d %	197.4^b folds		98.6^b folds
Limit	150^a	35^a		15^a
	50^b	25^b	20^b	10^b

^{a} USEPA. ^{b}WHO

4. Conclusion

The presence of PM and its associated components like black carbon and organic carbon is a threat to developing countries that relies more on fossil fuel burning and unchecked anthropogenic activities such bush burning, biomass (wood) fuel for cooking and emissions from industrial stacks. The air quality assessment was carried out using software model to investigate the influence of meteorological and terrain characteristics on dispersion of particulate matters from vehicles and backup generators (BUGs). ISC-AERMOD view simplicity was put to use in the line and point source study and the corresponding concentration which covers a 50 km by 50 km radius was noted. Line source study values are extremely higher due to emission height and prevailing meteorological condition of the university community, while the point source concentrations awre found to be moderate and this could attributable to the plume characteristics in stack emission such as stack height, wind direction and wind speed.

The results of this study indicate the need for an immediate action towards reduction of emission of pollutants especially from vehicles. Continuous inflow and outflow of traffic volume in the university community tends affect the health of the students, staffs, businessmen/women and receptor environment. More affordable hostels should be provided to reduce the number of students staying off-campus to an appreciable number. This will in turn reduce traffic inflow from commercial transports. It is also recommended that local regulatory bodies should set up a national fuel quality standard, implementing strict vehicle emission standards and the use of alternative fuels.

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