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Atmospheric ventilation corridors and coefficients for pollution plume released from an Industrial Facility in Ile-Ife Suburb, Nigeria

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This study presents a comparative investigation of atmospheric ventilation corridors and coefficients for gaseous pollution plume released from an isolated industrial facility into the ambient air of the host community in Ile-Ife suburb, southwest Nigeria. For the months of September to December in the year 2012 and 2013, measurement of surface layer atmospheric parameters made from an instrumented mast located near the industrial facility were used to parameterize for mixing layer height (MLH). Estimates of ventilation coefficients were obtained as well as in-depth analysis of the ventilation corridors performed. With an estimated carbon monoxide (CO) emission rate of 3.37 gs^{-1} from the industrial facility, AERMOD regulatory dispersion model was executed within a domain covering 8 km × 6 km around the host community. Effect of monthly changes in local ventilation corridors on pollutants dispersal at the study location was analyzed. Observed speed wind at the study location was weak (monthly mean value is ~ 1.5 m-s^{-1}). The wind direction was predominantly southwesterly, indicating ventilation corridors were towards the north-east of the region. Characteristic values of the atmospheric ventilation coefficients varied from month to month and from daytime (08:00 to 19:00, GMT+1) to nighttime (20:00 to 07:00, GMT+1) with daily maximum values occurring in the late afternoon between (13:00 to 17: 00, GMT+1). The maximum values obtained were 1216 m^{2}s^{-1}and 1156 m^{2}s^{-1}, 1760 m^{2}s^{-1} and 1038 m^{2}s^{-1}, 1225 m^{2}s^{-1} and 691m^{2}s^{-1}, and 1334 and 436 m^{2}s^{-1} for September to December, 2012 and 2013 respectively. Nighttime values were generally low, mostly less than 200 m^{2}s^{-1}. The study reveals that locations SE and NE of the scrap-iron recycling factory are prevalently exposed to high concentration of gaseous pollutants and the populace in those corridors is potentially susceptible to long-term adverse effects.

Key words: Air pollution, ventilation coefficient, ventilation corridors, dispersion, AERMOD.

INTRODUCTION

The corridors and extent to which gaseous pollutants will disperse in the atmosphere is dependent on a number of local meteorological conditions at the point and time of release from the emission source (Snyder et al., 2013;

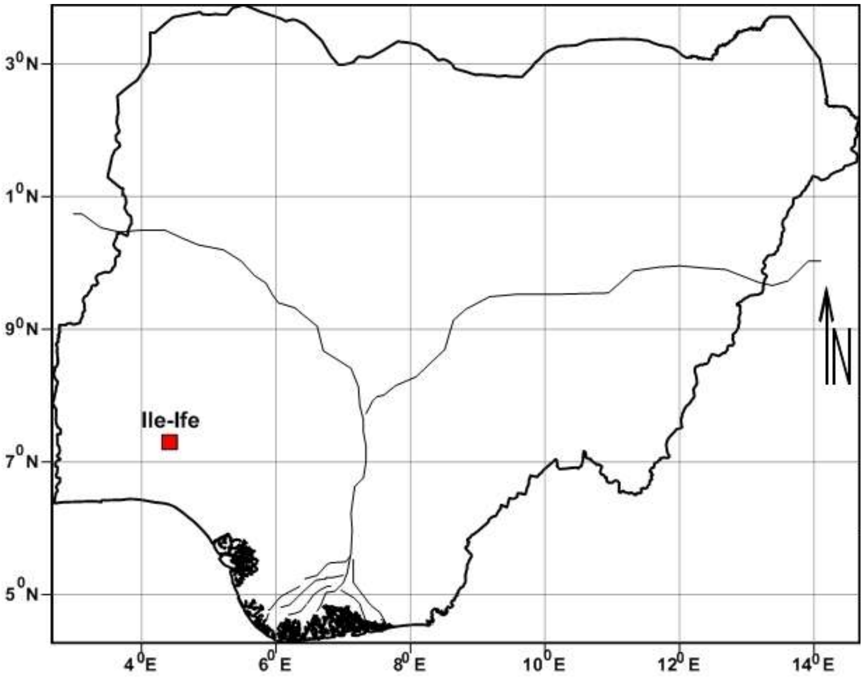

Figure 1. Map of Nigeria showing the location of Ile-Ife.

Vanos et al., 2015). These conditions include a measure of atmospheric ventilation coefficient which is a combination of wind shear due to vertical wind speed gradient and mixed layer height (MLH) within the atmospheric boundary layer (ABL) (Sujatha et al., 2016). Wind direction, atmospheric lapse rate, and surface layer characteristics such as roughness length and albedo among others also have significant contributions in this regard. However, the dominant meteorological parameters used in determining the ventilation corridors and capacity of the atmosphere to disperse pollutants are wind speed and wind direction (Harrison, 2006; Longley et al., 2015). This is because downwind dispersal of atmospheric pollutant from source-point is more sensitive to wind speed and wind direction than any other parameter (Iyer and Raj, 2013). Richard et al. (1994) have shown that a shift in wind direction as little as 5° (the approximate accuracy of a wind direction measurement), venting gaseous pollutants towards a particular location may cause concentration at the location to vary significantly. A variation up to about 10% under unstable conditions, 50% under neutral conditions, and about 90% under stable conditions could occur. As such, estimates of the atmosphere's dispersive capacity (ventilation coefficient) and ventilation corridors for toxic gaseous pollutants released into the ambient environment from industrial facilities are required for assessment of potential impacts of elevated concentrations of such releases (Genc et al., 2010; Lu et al., 2012).

The investigation of ventilation corridors and dispersive potential of the atmosphere is thus very important in impact assessment of air pollution sources especially where there are sensitive receptors or in the case of litigation involving sources not far apart. In this study we measured in-situ meteorological parameters, the first of such measurement in Nigeria, in order to estimate the atmospheric mixing potential for gaseous pollution plume released from a scrap-iron recycling factory in Ile-Ife, southwest Nigeria. This is aimed at providing detailed knowledge on the prevailing ventilation corridors and predicting the locations most susceptible to pollution plume due to the operations of the scrap-iron recycling factory which for long, have constituted serious environmental hazard to the host community (Owoade et al., 2013).

MATERIALS AND METHODS

Site description

The study site for meteorological measurement (262 m a.s.l) is shown in Figure 1. It is located in Ile-Ife, along Ife-Ibadan expressway and in close proximity (roughly 150 m) to the targeted scrap-iron recycling factory (7°29'N, 4° 28'E, 258 m asl). The factory

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is situated in Fashina, a low income community situated in Ife-Central Local Government Area of Osun state. A detailed description of the meteorological sensors deployed the surface characteristics and prevailing weather condition of the location has been given in Abiye et al. (2016).

Meteorological parameters

In air pollution assessment studies, the importance of obtaining reasonable estimates for MLH within the atmospheric boundary layer cannot be over emphasized (Jegede, 1994; Emeis et al., 2004). The MLH is the height to which the lower atmosphere will undergo mechanical or thermal mixing, producing nearly a homogeneous air mass (Arya, 1999). Direct methods of obtaining the MLH include the use of 00:00 GMT radiosonde sounding and SODAR (Gera and Saxena, 1996; Beyrich, 1997). However, the resources available for this study could not cover the cost of launching radiosondes.

An alternative technique is therefore to parameterize for the MLH using simple models which requires only a few routinely measured meteorological parameters (Feng et al., 2015). As such, for the period of the study in September to December, 2012 & 2013, site specific measurement of routine meteorological parameters were obtained from a 6-m mast, installed near the industrial facility (about 200 m from the fence line).

The instrumented 6-m mast carried surface recording meteorological devices (highly sensitive and well calibrated sensors such as, cup anemometers, air temperature and relative humidity sensors, radiometers for global and net radiation, and soil heat flux plates) was co-located with the scrap-iron recycling factory. Wind speed was recorded at two levels (1 and 5.5 m), wind direction (5.5 m), net and global radiation (1.5 m), temperature and relative humidity (1 and 5 m), soil temperature and heat flux (depths of 2 cm and 5 cm respectively). Continuous measurements (sampling every 10 s) of the meteorological parameter were made for the entire period of study. The measured parameters were reduced to their respective hourly averages.

In all, eight months of meteorological data containing approximately 5, 760 hourly data points for each parameter were analyzed. From the meteorological dataset, the MLH was parameterized based on Equation 1 (Cimorelli et al., 2004) for stable and neutral conditions (z_{im}) while we adopted Equation 2 (Giovannoni, 1993) for the convective periods (z_{ic}). In applying the MLH, we have considered the highest of the values obtained between stable and unstable conditions (Cimorelli et al., 2004). Equation 3 gives the estimation expression for friction velocity.

$$z_{im} = 2300 u_*^{3/2} \tag{1}$$

$$z_{ic} = -kL\left(\frac{\omega_*}{u_*}\right)^3 \tag{2}$$

$$u_* = \frac{ku}{\ln\left(z_{ref}/z_0\right) - \Psi_m\{z_{ref}/L\} + \Psi_m\{z_0/L\}} \tag{3}$$

u_*, ω_* and L are friction velocity, convective velocity scale and Monin-Obukhov length respectively. k is the Von Karman constant (0.4), u is the reference height wind speed (meters/second), z_{ref} is the reference height and z_0 is the surface roughness length.

The dimensionless stability functions Ψ_m are given by

$$\Psi_m\left(z_{ref}/L\right) = 2\ln\left(\frac{1+\mu}{2}\right) + \ln\left(\frac{1+\mu^2}{2}\right) - 2\tan^{-1}\mu + \frac{\pi}{2} \tag{4}$$

$$\Psi_m\left(z_0/L\right) = 2\ln\left(\frac{1+\mu_0}{2}\right) + \ln\left(\frac{1+\mu_0^2}{2}\right) - 2\tan^{-1}\mu_0 + \frac{\pi}{2} \tag{5}$$

$$\mu = \left(1 + 16\, z_{ref}/L\right)^{\frac{1}{4}} \tag{6}$$

$$\mu_0 = \left(1 + 16\, z_0/L\right)^{\frac{1}{4}} \tag{7}$$

Since Ψ_m is a function of L, and L is a function of u_*, an iterative solution is obtained by setting the initial value of Ψ_m to zero. The final estimate is made when the values converged (that is, difference between successive values is less than 10%). Weibull scale and shape factors, c and k respectively (Kantar and Senoglu, 2008) for the wind distribution at the study site were obtained from mean wind speed and standard deviation method (Shoji, 2006).

Ventilation coefficients and corridors

The ventilation coefficient V_{-co} (m^2s^{-1}) which is a measure of atmospheric transport and dilution of gaseous pollutants species in air within the atmospheric boundary layer was estimated as a product of the parameterized MLH (m) and mean wind (ms^{-1}) near the ground surface as in Equation 4 (Ashrafi et al., 2009; Lu et al., 2012). For the purpose of this work, wind speed measured at 5.5 m near scrap-iron factory has been used in order to fully represent the meteorological conditions at the point of release of the pollution plume. Hourly averages of wind speed and wind direction data were analyzed for frequency distributions in sixteen ventilation corridors (wind-sectors). The wind directions were averaged following meteorological monitoring guidance for regulatory modeling applications (U.S. EPA, 2000) given in Equations 9 to 12.

$$V_{-co} = \bar{u}Z_{ic.im} \tag{8}$$

$$V_x = -\frac{1}{N}\sum Sin\theta_i \tag{9}$$

$$V_y = -\frac{1}{N}\sum Cos\theta_i \tag{10}$$

$$\bar{\theta}_{UV} = tan^{-1}\left(V_x/V_y\right) + FLOW \tag{11}$$

$$FLOW\ (degrees) = \begin{cases} +180, & tan^{-1}\left(V_x/V_y\right) < 180 \\ -180, & tan^{-1}\left(V_x/V_y\right) > 180 \end{cases} \tag{12}$$

where N is the number of wind directions to be averaged, V_x and V_y are horizontal and vertical components of the wind direction respectively, θ_i and $\bar{\theta}_{UV}$ are the instantaneous and resultant wind directions respectively, in degrees. Wind roses depicting dominant wind flow sectors at the study location were plotted using Lakes Environmental proprietary window based program WRPLOT View (Jesse et al., 2011). The program was also used to assess occurrences of calm conditions ($u < 0.5$ ms^{-1}) at the study location and the ventilation corridors for pollution plume were graphically illustrated using appropriate mapping tools.

Emission rate estimate

Source emission rate of CO was estimated based on AP-42 documented emission factor methodology (US EPA, 1995). This was because source-specific measurements were not available for the factory. As such, the AP-42 methodology provides the best and most frequently adopted alternative for emission rate estimations. The general equation for estimating emission rates (US EPA, 1997) is given by:

$$E = A \times EF \times \left[1 - \frac{ER}{100}\right] \quad (13)$$

where, E = emission rate, A = activity rate, EF = emission factor, and ER = overall emission reduction efficiency (%). Five log sheets documenting daily material consumption (scrap metals, alloying agents and fluxing materials) and tonnes of billets were produced from different batch process in 2012 were averaged to obtain total material input per day. The total material input was taken as the activity rate and the characteristic emission factor typical of a scrap-iron recycling facility was adopted from AP-42 (US EPA, 2009). In obtaining the estimate of source emission rate, the following assumptions were made (i) pollutants emission occurs at two points in the process line: during charging of scrap metal in the EAF and during refining process in the ladle (ii) emission from aggregate material handling, storage piles, paved and unpaved road traffic were considered insignificant (iii) information on the randomly selected log sheets used in compiling activity rate which are representative of the daily operation routine at the smelting facility. An estimate of ground level concentration of CO in the plume was obtained by executing a Gaussian-based regulatory model AERMOD (Cimorelli et al., 2004) within a domain of 8 × 6 km with 50 m resolution.

RESULTS AND DISCUSSION

Ventilation corridors

Statistics of the wind speed classes together with the Weibull distribution parameters (scale factor c and shape factor k) obtained for each month are presented in Table 1a. A summary of the occurrence of wind direction in sixteen wind sectors at the study location are presented in Table 1b. From the tables, wind speed at the study location was observed to be generally weak - the monthly mean was typically less than 1.5 ms^{-1}. The most prominent wind speed classes are those between 0.5 to 2.0 ms^{-1} which contributes between 41.2 to 78.9% monthly. In all the monthly data analyzed, frequency occurrence of wind classes 0.5 to 1.0 ms^{-1}, 1.0 to 1.5 ms^{-1}, 1.5 to 2.0 ms^{-1} are between 12.5 to 27.4%, 17.0 to 33.3% and 10.2 to 27.4% respectively. Calm conditions (wind speed < 0.5 ms-1) were not observed in 2012. Thereafter, the occurrence of calm conditions showed an increasing trend from October to December 2012. Similar pattern of calm conditions were repeated in 2013 except for a slight drop from 35.8% in October to 34.3% in November. The month of December 2013 which recorded the highest occurrence of calm condition (49.1%) may probably experience significant wind flow stagnation resulting in poor ventilation and high concentrations of pollutants near the factory. The diurnal variations of wind speed and wind direction for the study period are shown in Figure 2. From the figure, it was observed in 2012 that night times (01:00 to 08:00 LST) recorded more fluctuations and even more pronounced particularly in the transition months October and November. This implies that at night when the atmosphere is often stable, more locations across the domain considered in this study were impacted with pollution load than in day time.

From the wind direction and wind speed frequency distribution analysis for the month of September 2012 (Table 1a and b), it was observed that the wind was blowing from the North West (NW) and South West (SW) direction only. Predominantly, wind flow from West South West (WSW) and NW direction contributed approximately 20 and 18% respectively to the ventilation corridors in the area. The ventilation corridors in the month of September 2012 shows that areas lying SW and NW of the scrap-iron recycling factory are less prone to pollution episodes because the pollution plumes spread only eastward of the source. The corridors of pollutants ventilation due to these wind fields are towards the NE and SW. Hence, locations such as Obafemi Awolowo University (O.A.U) Campus, Modomo and Fashina settlements lying in these wind corridors are susceptible to high concentration in the month of September. Within these corridors, wind speed greater than 3 ms^{-1} occurred frequently in the WSW direction more than any other direction. Thus, the relatively strong winds as compared to the periods average of less than 1.5 ms^{-1} for the study location, can be attributed to the dispersal of 400 µgm^{-3} of CO towards locations in Modomo area and Ede road while locations west of the factory (≥ 200 m away from the north-south geographic axis) are observed to have low concentrations (Figure 3). Figure 3c and d show the distribution of CO concentrations for the months of October and November 2012 respectively. Maximum concentrations value of pollution increased from 1095.6 µgm^{-3} in October to 1593.9 µgm^{-3} in November. The margin between these estimated values represent an increment of about 45% of CO concentrations impacting on the ambient environment in the month of November as compared with the values obtained in October. These maximum concentrations values which were observed to, occur during the early morning hours (01:00 to 08:00 LST), impact the same grid location and in turn producing higher short-term averages. These can be attributed to the similarity in the wind flow for the two months especially during the night hours when the fluctuations in the ventilation corridors is high (Figure 2a and b).

Table 1. Wind Speed and Wind Direction Frequency Distribution and Weibull Parameters for 2012 and 2013.

(a)	**Wind Speed Frequency Distribution (%)**							**Mean**	**Max**	**Weibull Parameters**	
(ms^{-1})	**Calm**	**0.5 - 1.0**	**1.0 - 1.5**	**1.5 – 2.0**	**2.0 – 2.5**	**2.5 – 3.0**	**>3.0**	**(ms^{-1})**		**Scale factor c**	**Shape factor k**
				Year 2012						**Year 2012**	
Sept	-	19.6	33.3	25.0	13.1	6.5	2.4	1.5	3.3	1.57	0.40
Oct	5.4	26.5	25.2	27.0	10.0	3.7	2.2	1.4	4.2	1.42	0.48
Nov	11.9	25.0	26.5	27.4	7.5	1.0	0.7	1.2	4.1	1.24	0.51
Dec	28.6	12.5	19.0	24.1	11.3	4.2	0.3	1.1	3.0	1.17	0.71
				Year 2013						Year 2013	
Sept	14.6	27.4	26.4	16.5	8.0	4.8	2.2	1.2	5.2	1.25	0.63
Oct	35.8	20.7	21.0	14.8	5.2	1.9	0.7	0.9	4.0	0.91	0.83
Nov	34.3	22.5	23.8	13.2	4.2	1.7	0.2	0.9	3.0	0.89	0.78
Dec	49.1	18.8	17.0	10.2	3.9	1.1	-	0.7	2.9	0.69	1.03

(b)	**Wind direction frequency distribution (%)**															
	N	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**
									Year 2012							
Sept	1.48	-	-	-	-	-	-	-	3.86	5.35	10.41	19.94	15.40	13.39	18.45	11.60
Oct	-	0.24	1.71	3.18	6.12	5.39	5.88	5.14	4.9	8.30	12.25	19.11	13.97	6.12	1.96	0.24
Nov	-	0.13	0.97	2.77	3.61	5.83	5.27	4.30	5.5	7.77	10.41	15.69	12.64	7.91	3.88	1.25
Dec	-	0.29	2.08	0.29	1.19	0.89	2.97	1.78	2.97	2.97	10.41	15.47	9.22	9.82	8.60	2.30
									Year 2013							
Sept	-	-	-	-	-	-	-	-	-	0.16	30.92	39.58	9.13	3.68	1.12	0.80
Oct	-	-	-	-	-	-	-	-	-	-	19.75	26.20	10.88	5.51	1.34	0.53
Nov	-	-	-	-	-	-	-	-	-	0.25	26.47	21.81	12.50	3.10	0.70	0.70
Dec	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**17.90**	**16.35**	**9.41**	**3.54**	**3.24**	**0.46**

For both months, the wind flow originated from either SW or SE. The largest percentages of wind distribution 45 and 49% for October and November respectively came from the SW, WSW and West (W) directions. The month of October recorded a slightly higher wind speed occurrences for almost all the wind speed categories and more frequency counts in all the corresponding wind directions (Table 1). Roughly, 12% of the hourly wind flow for November was calm conditions (≤ 0.5 ms^{-1}), which was twice the calm conditions in October. This could be an explanation for the greater dispersion of pollutants observed in the month of October as compared to November. Also, the month of November is a transition month between wet and dry season mostly marked by heavy rain falls which often lead to wet deposition of the pollutants. The high concentrations values estimated to occur near the scrap-iron-recycling factory in November could be as a result of the pronounced calm condition (~ 12 %, Table 1b). The ventilation corridors and concentrations isopleths for the month of December 2012 are presented in Figure 4b. Unlike the previous months, the pollutants' spatial distribution in the month of December showed a different pattern. It is observed to have a fairly even distribution of concentration isopleths in nearly concentric arcs around the scrap-iron recycling factory. Though the maximum estimated concentration of 1500

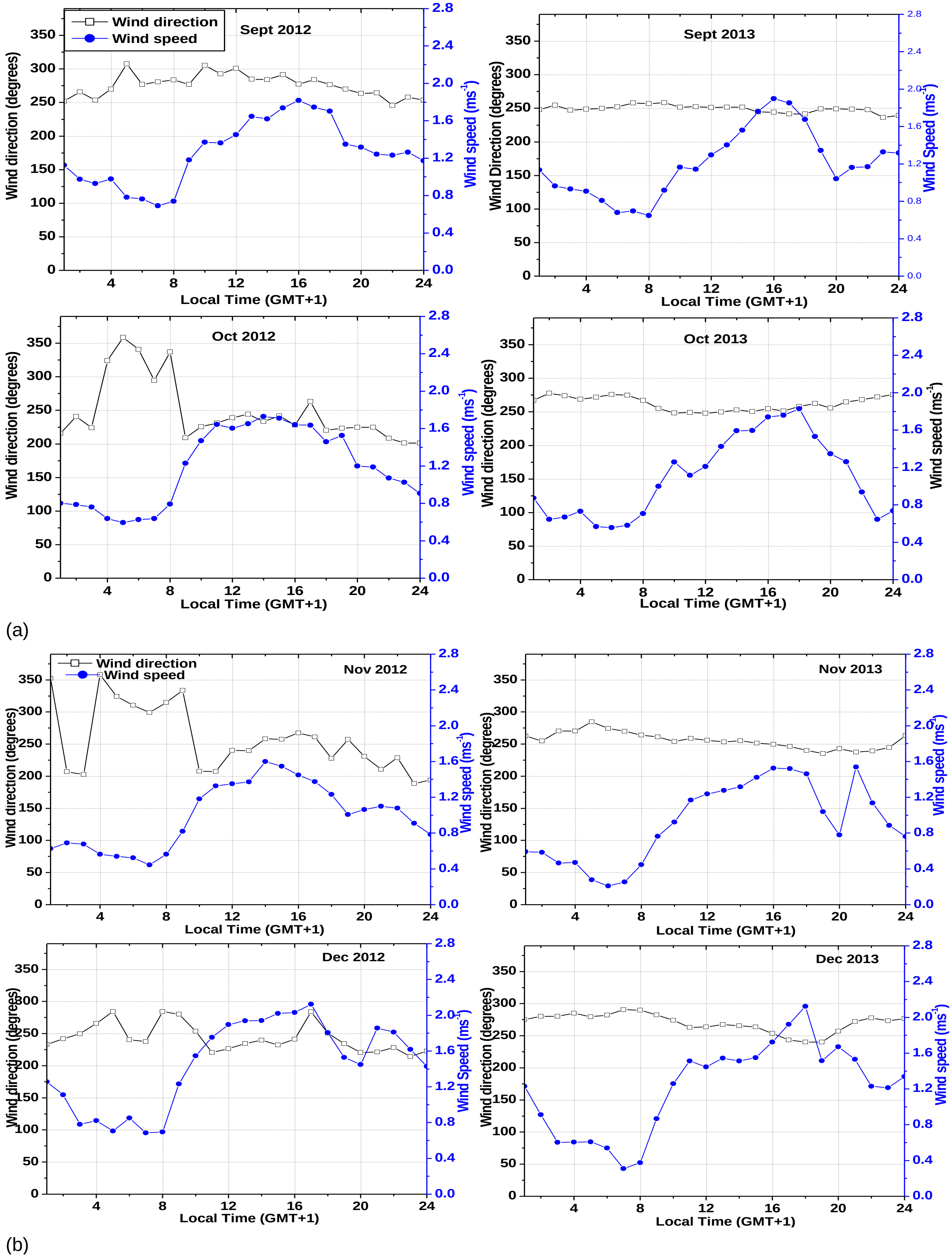

Figure 2. Comparison of diurnal variation of wind speed and wind direction for September and October (top panel) November and December (bottom panel) at the study location.

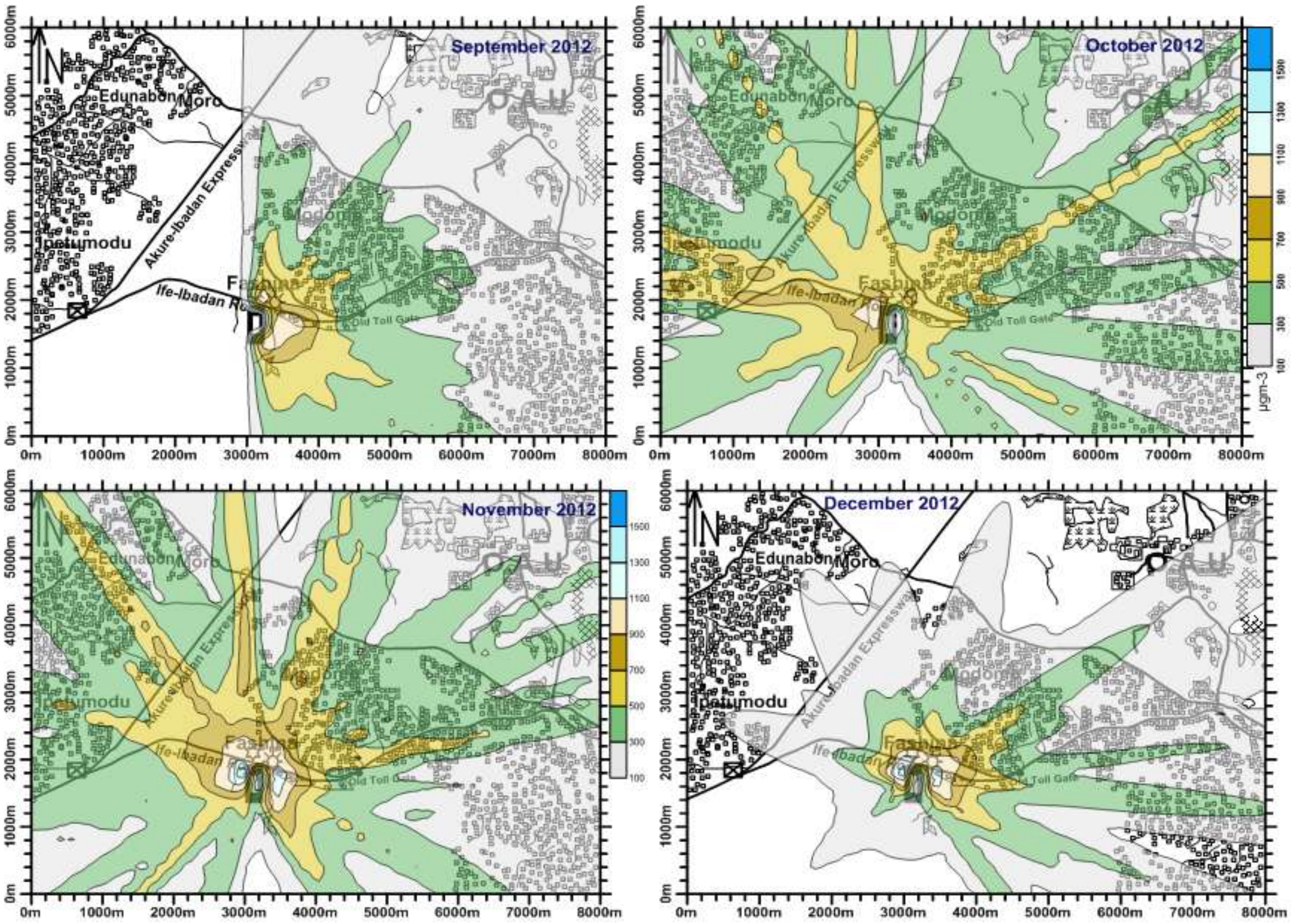

Figure 3. Ventilation corridors and concentration spread (color scale in µgm^{-3}) for CO in the months of Sepetember (top left), October (top right), November (bottom left) and December (bottom right) in the year 2012.

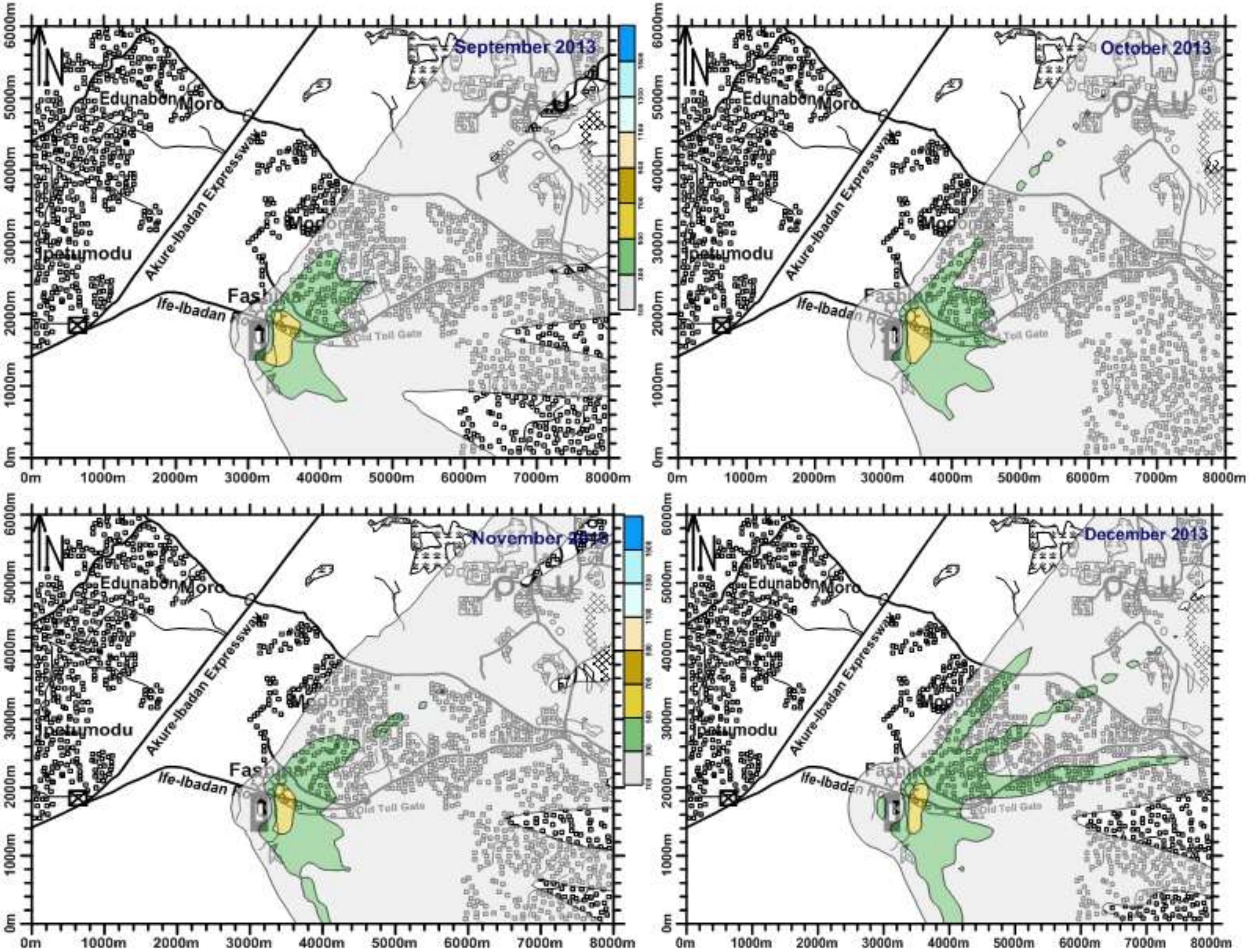

Figure 4. Ventilation corridors and concentration spread (color scale in µgm^{-3}) for CO in the months of Sepetember (top left), October (top right), November (bottom left) and December (bottom right) in the year 2013.

μgm^{-3} for CO ranked 2nd to that of November in the year 2012, the concentration isopleths revealed that the pollutants were less vented from the source as compared to the previous months. This can be attributed to increased occurrence of calm conditions (Mahalakshmi et al., 2011) up 29% in December as against 12% in November. As such, there is tendency for lesser degree of pollutants advection along the downwind direction. When weak advection is prevalent as indicated by the wind conditions in December, released pollutants are subject to gravitational settling and downwash at locations close to the scrap-iron recycling factory. The isopleths also revealed that 98th percentile of CO concentrations impacting on the ambient environment is observed to be within an arc of approximately 500 m away from the scrap-iron recycling factory in the east direction. In 2012, the epicenters of maximum concentrations which are observed to occur mostly in the East of the factory were, slightly displaced Southwards in December.

Spatial distributions of CO concentrations emitted from the scrap-iron recycling factory for September to December 2013 are presented in Figure 4. In September, daily maximums of sensible heat flux reached up to 140 Wm^{-2} thereby making the surface warm. The sensible heating near the surface provides the energy required for enhanced mixing of gaseous pollutants due to updraft and downdraft motion of air parcel around the scrap-iron-recycling factory. This probably explains why September has lesser distributions of high concentrations because once the emissions are entrailed into the ambient environment they subject to a more bouyant atmosphere and became easily dispersed. From Figure 3 g and h, it is observed that the maximum concentration for CO were similar for the months of October and November. In December, the 98th percentile of CO (457 μgm^{-3}) concentrations distributions were comparatively higher than October and November. Though it was observed that October and November recorded maximum CO concentration values > 700 μgm^{-3} which were higher than the values estimated for December, the percentiles' distribution analysis clearly indicate that concentrations were more skewed to the higher values in December than the previous months. This can be attributed to the increased occurrence of calm conditions resulting in poor ventilation (He et al., 2016). It was observed that frequency distributions of wind speed and wind direction categories for October, November and December, 2013 were similar except that they recorded 35.8, 34.3 and 49.1% occurrence of calm condition respectively (Table 1). These frequencies of calm condition occurence are the three highest for the months under consideration in 2012 and 2013. The effect of the calm conditions on pollutant dispersion was observed to, limit the spread of pollutants in December, where maximum concentrations were estimated to occur at locations much closer to the scrap-iron recycling factory. This could possibly be attributed to, the effect of the pronounced calm conditions that were recorded in December (49.1%).

Ventilation coefficients

Diurnal variation of the estimated ventilation coefficients (V_{-co}) at the study site are shown in Figure 5, presented in Table 2 and given the statistics for the entire periods in each year. It is observed that V_{-co} varied from month to month and from daytime to nighttime with daily maximum values occurring in the late afternoon between 13:00 to 17: 00 GMT+1. The maximum values obtained from September to December, 2012 and 2013 were 1216 and 1156 m^{2}s^{-1}, 1760 and 1038 m^{2}s^{-1}, 1225 and 691m^{2}s^{-1}, 1334 and 436 m^{2}s^{-1} respectively. Generally, the V-co obtained during daytime (8:00 to 19:00 GMT+1) were higher than nighttime (20:00 to 07:00 GMT+1). While the daytime values varied significantly from sunrise to sunset, the nighttime values were relatively stable (< 200 m^{2}s^{-1}) except for November and December 2012, where the values between sunset and midnight (20:00 to 24:00 GMT+1) were up to 400 and 800 m^{2}s^{-1} respectively. The high V-co obtained during daytime is indicative of a favorable atmospheric condition for efficient dispersal of gaseous pollutants away from the scrap-iron recycling factory (Genc et al., 2010). On the other hand, the nighttime values suggest that dispersion of the gaseous pollutants is likely to be limited and may result in poor air quality in the vicinity of the scrap-iron recycling factory (Goyal et al., 2006). Monthly comparison shows that daytime V-co values obtained for September, October, November and December 2012 were consistently higher than the corresponding months in 2013 by 20 to 295%, 4 to 620%, 57 to 580% and 120 to 450% respectively. This trend clearly indicates that the dispersive capacity of the atmosphere reduced significantly from 2012 to 2013. Since the V-co is dependent on wind speed and mixing height, these reductions may be attributed to high values of mixing depth in 2012 compared to 2013 given the observations that the wind speeds were similar in both years. Hence, it can be deduced that gaseous pollutants may be expected to have more dispersion along downwind corridors from the source in 2012 than in 2013. Also, pollutants concentration distribution is expected to cover a wider area in 2012 as seen in the Figures 3 and 4. The implication is that while locations farther away from the scrap-iron recycling, factory recieves little or no pollution in 2013 locations, in the viccinity of the factory which may be susceptible to higher concentration values than the previous months in 2012.

The results obtained in this study were similar and comparable to previous study. For instance, Lu et al. (2012) investigated the characteristics of V-co and its impacts on air pollution in Changshe, China using mean wind speed at 10 m and predictions of MLH by HYSPLIT model. Diurnal trend observed wind speed (1.1 to 3.5 ms^{-}

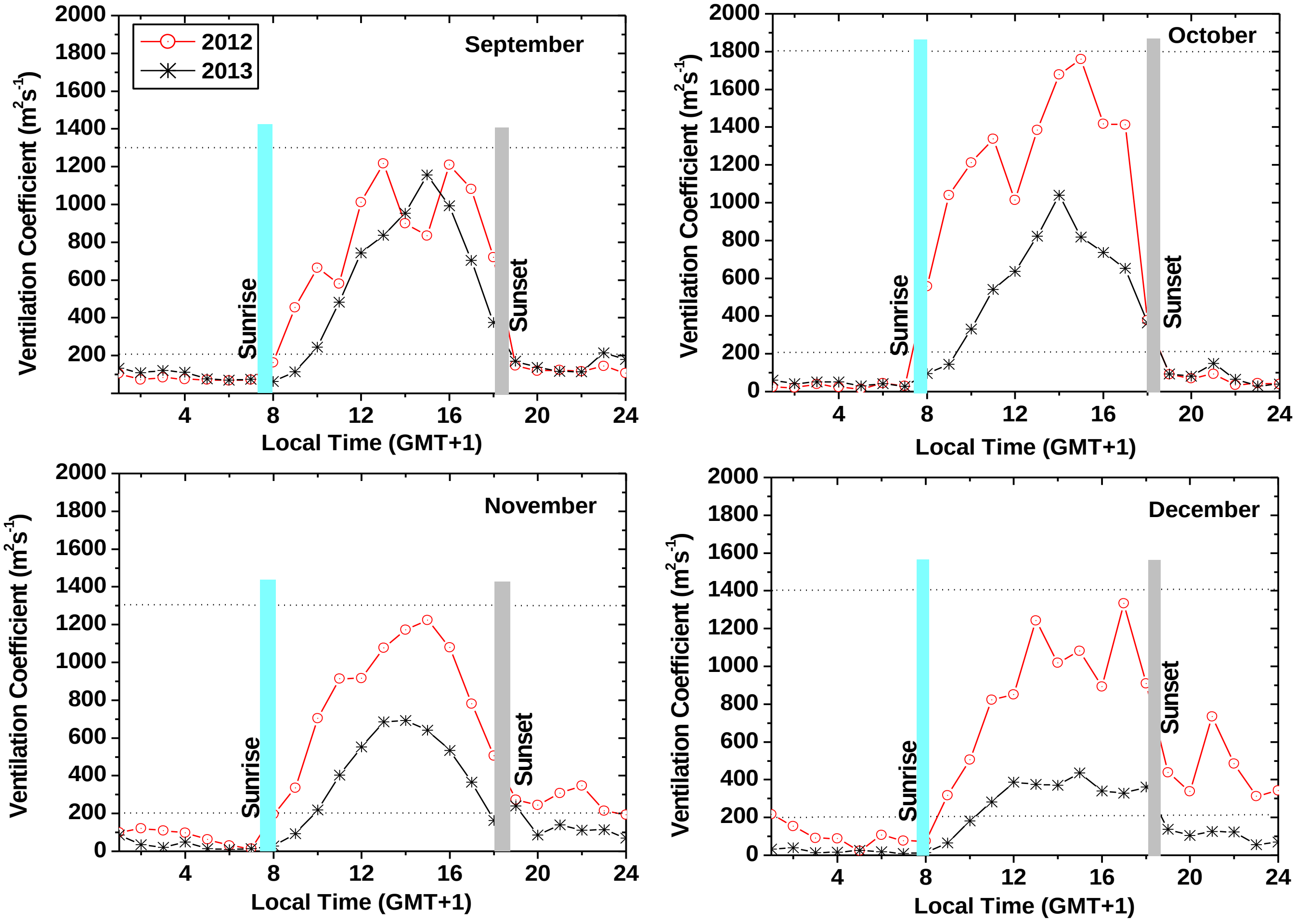

Figure 5. Diurnal variation of estimated ventilation coefficients in 2012 and 2013.

Table 2. Statistics of Ventilation Coeffients obtained for the study period (September – December) in 2012 and 2013.

Local time	2012 (m^2s^{-1})				2013 (m^2s^{-1})			
(GMT+1)	Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max
01	112	79	24	216	79	43	33	134
02	93	58	22	155	57	35	35	109
03	81	30	39	110	51	49	13	120
04	70	33	23	97	57	39	17	111
05	44	28	15	71	37	27	14	76
06	63	34	31	108	35	27	9	69
07	48	31	14	77	31	30	8	75
08	247	212	74	556	50	37	13	97
09	536	341	316	1040	104	34	64	145
10	772	307	505	1213	245	64	182	331
11	914	315	581	1338	427	112	281	541
12	948	79	851	1014	580	150	388	743
13	1230	127	1076	1385	680	215	374	836
14	1192	343	900	1678	763	301	370	1039

Table 2. Contd.

15	1225	391	836	1760	763	305	436	1156
16	1150	222	892	1418	651	279	341	992
17	1153	285	781	1413	513	192	329	703
18	628	234	378	908	317	102	164	376
19	237	154	91	437	161	62	93	240
20	193	122	70	339	103	25	82	136
21	315	295	93	733	133	14	117	148
22	246	207	35	486	104	26	65	124
23	178	113	43	312	104	81	31	214
24	171	131	39	343	89	61	39	179

^{1}), MLH (210 to 1 500 m) and V-co (250 to 5 000 m^{2}s^{-1}) are of the same order with results of present study. Range of values (200 to 900 m^{2}s^{-1}) obtained during nighttime by Lu et al. (2012) are also the same here. Using wind speed at mean MLH, Ashrafi et al. (2009) also estimated V-co values between 7 900 to 22 400 for Tehran, Iran. Low values were reported to occur between September to November and high values frequently occurred around April to June. In a similar study by Sujatha et al. (2016), monthly mean of V-co for the urban city of Hyderabad, India over a period of three years (2009 to 2011) have been reported. In the study, highest value of V-co *(*19,735 m^{2}s^{-1}) was observed during the month of May and the lowest (13,331 m^{2}s^{-1}) in January. When compared with the present study, values obtained by Sujatha et al. (2016) were ten times higher. This was due to high mixing heights obtained from the LIDAR instrument and strong winds up to 16 ms^{-1} observed in their study. In general, it is observed that V-co is significantly sensitive to prevailing wind conditions at the study locations and to some extent on the methodology employed in deriving the mixing layer height (MLH).

Conclusion

The ventilation corridors and coefficient for gaseous plume released from a scrap-iron recycling factory have been, estimated from meteorological parameters measured at the study location in Ile-Ife, Southwest Nigeria for the periods of September to December, 2012 and 2013 respectively. Analysis of the surface flow in 2012 showed that the wind was blowing predominantly between SSW (about 2.97 to 8.30%) and NW (1.96 to 18.45%) with minor contribution from other wind sectors. For the months in 2013, the wind was blowing predominantly from wind sectors between SW and WNW. Maximum concentration of CO were estimated to occur during morning hours prior to sunrise and in the evenings after sunset when the wind speeds are low and mixing depth are mostly below 200 m. Consequently, the low values of estimated V-co obtained strongly indicate that, periods between sunset and sunrise have high potential for elevated pollutants concentration levels in the host community.

Conflict of Interests

The authors have not declared any conflict of interests.

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