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AMBIENT LEVELS OF GASEOUS, PARTICULATE AND BIO-AEROSOL POLLUTANTS IN FARM SETTLEMENTS ACROSS OGUN STATE, SOUTHWEST NIGERIA

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ABSTRACT

This study assessed the levels of air pollutants emitted outdoor of farm settlements (FS), the seasonal and temporal variations, and the relationship among the parameters monitored. Seven FS within Ogun State were investigated, with 211 sampling points established across the FS. The concentrations of VOCs, SO_2, NO_2, CO, O_3, NH_3, CO_2, TSP, $PM_{2.5}$ and PM_{10} were monitored in replicates using active potable samplers while bacteria and fungi were isolated using settle plate technique. Descriptive (means and standard deviation) and inferential statistical tools (Pearson correlation) were used to analyse the data. The mean ranges of VOCs, CO and CO_2 (ppm); 20.8±10.53 – 48.67±19.05, 17.95±6.65 – 21.5±3.93, 3562.15±1200.85 – 4266±1176.85, and for bacteria and fungi (cfu/m^3); 548.98±1.18 – 2255.01±1.27 and 525.68±1.15 – 1282.38±1.27 respectively were above the threshold limits. There were significant seasonal, spatial and temporal differences among observed means of VOCs, CO_2 O_3, TSP, $PM_{2.5}$, and fungi. The bacteria and fungi count increased as TSP, $PM_{2.5}$ and PM_{10} increased. The study established that levels of air pollutants are dependent on the type of farming practice.

Keywords: Agriculture, Outdoor, Air pollutants, Bio-aerosols, Farm settlements.

INTRODUCTION

Extensive agricultural processes involve deforestation, slashing and burning, fertilization, the introduction of agrochemicals, vaccines, antibiotics, antimicrobials, processing and packaging of farm produce for sale (Bhandari, 2014) and mostly from bad farming practices (Harizanova-Bartos and Zornitsa Stoyanova, 2018). At some instances, massive mechanization and labour may be included. According to Rohila *et al*. (2017), farming has a more significant impact on the environment than any other single human activity. Hinz (2002) reported that agriculture is the source of various materials that can affect all compartments of the ecosystem (air, water, soil, plants and humans), while at the same time acting as the receptor of many contaminants from different environmental sources. The nexus that exists between agriculture and the environment is highly sophisticated than typically predicted in chain-emission exposure and impact transmission. Aneja et al. (2009) reported that in the United States, agricultural emissions play an essential role in multiple environmental and public health issues processes with consequent impact on local and regional environmental quality. Nevertheless, Jager (2005) and Arslan and Aybek (2012) identified significant hazards resulting from organic and inorganic particulates, contaminants, pollutants, and infectious agents (including public health concerns from the burden of bio-aerosol emissions from farm buildings). Seedorf (2004) believed that these emissions play critical roles in respiratory disorders in those living near animal industries, which can be transmitted from and via animal houses (Schulz *et al*., 2005).

FAO (2015) noted the global impacts of fire land clearing, plant residue burning; livestock methane; fertilizer and manure nitrous oxide; and manure and urine ammonia, which caused air pollution in tropical regions far from the emission sources. The studies of Dungan (2010) and Samadi *et al*. (2013) on different agricultural activities, especially animal husbandry and veterinary practices with particular reference to atmospheric pollutants including microorganisms transport through the air have confirmed occupational risk to farmers residing around livestock buildings for pig, cattle and poultry farms (Eisenberg *et al*., 2010; Sowiak *et al*., 2011; Brodka *et al*., 2012).

Hence, with the recent trend in the outbreak of air-related diseases especially those of animal origin, and consistent lowering in living standards, there is the need to assess the levels of air pollutants in farm settlements. Since previous studies have indicated probable air pollutants related to agricultural systems and activities, this study identified the specific agricultural activities in each FS, monitored outdoor air pollutants levels and relate such pollutants to the main agricultural practice in the specific FS.

MATERIALS AND METHODS

Description of the study area

Ogun State was created in 1976 and located in the Southwest region of Nigeria. It borders Lagos State to the South; Oyo and Osun States to the North; Ondo to the Southeast; and the Republic of Benin to the Northwest, and lies on latitude 7°00´N and longitude 3°35´E. Abeokuta is the capital and the largest city in the State. The total population of 3,751,140 residents was registered in 2006, comprising 1,864,907 males and 1,886,233 females (NPC, 2006) occupying a land area of 16,409.26 km^2. The State is blessed with a favourable climate and good vegetation throughout the year with evergreen forest vegetation and soil suitable for growing cash and food crops such as oil palm, rice, kola nut, cocoa, cassava, cocoyam and vegetables in the southern part of the State; while in the north, there is a large savannah region suitable for animal husbandry (OGSG, 2017). There are eight farm settlements distributed across the State. These include Ado-Odo, Ago-Iwoye, Ajegunle, Coker, Ibiade, Ikenne, Ilewo-Orile, and Sawonjo. All the FS except Ilewo-Orile were selected for this study (Figure 1) because as at the time of this study, the Ilewo-Orile FS was not in operation.

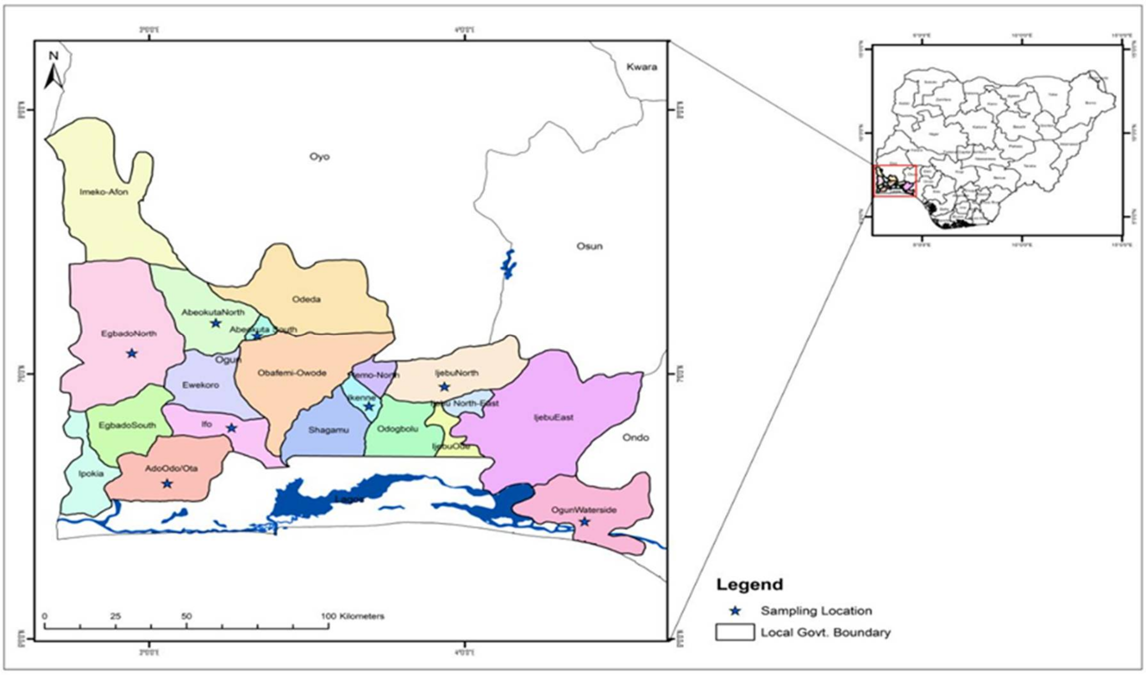

Fig. 1: Map of Ogun state showing the locations of selected farm settlements

Sources and types of data

In this study, both secondary and primary data sources were employed. Secondary data was collected from Farm Officers employed by the Ogun state government, and it included all necessary and available information about each farm settlement. In contrast, the primary data sources included information collected through observation, field measurements and laboratory analysis concerning the objectives.

On-site observation

A walk-through and on-site physical observation of the FS was carried out to ascertain the information given by the Farm officers on the type of agricultural activities.

Air quality monitoring

Air quality monitoring was conducted for the dry season (December 2017 and February 2018), wet season (May and July 2018); between 8 am – 10 am for morning and 5 pm – 7 pm for the evening samplings. Measurements were taken at 5 minutes intervals during the two-hour monitoring. Active hand-held in-situ samplers were used for both the gaseous pollutants and PM monitoring. The Thermo Scientific MIE pDR-1500 model particulate counter has three cyclones specific for each particle size (TSP, PM_{10}, $PM_{2.5}$) cut-off. Each of the parameters was monitored after changing the filter paper to take a new reading at different sampling points. The equipment was adequately set-up before sampling to ensure the accuracy of the readings displayed.

Bioaerosol sampling

Two types of solid media – Nutrient Agar (NA) for bacteria and Potato Dextrose Agar (PDA) for fungi were prepared according to manufacturer's specifications and poured into labelled 92 mm Petri dishes. The NA was enriched with glucose, and PDA was supplemented with antibiotics to inhibit the growth of unwanted organisms). These media were left open for 30 minutes for gravity settling/collection (sedimentation/open plate) of bioaerosol at the height of 1 m from the floor and at a distance of about 1m from the wall or any object as described in Napoli *et al*. (2012). The main precaution taken during the sampling time was to avoid talking, sneezing and walking. The dishes' lids were replaced at the end of the exposure period. The plates were transported in a clean container to the laboratory and incubated at 37°C for 18-24 hours for bacteria and 27°C for 48-72 hours for fungi (Wemedo *et al*., 2012). The number of colonies expressed as CFU m^{-3} was calculated by using the Koch's sedimentation method of Settle Plate Technique (Polish standard 89/Z04008/08) described by Stryjakowska-Sekulska *et al*. (2007) and Morakinyo *et al*. (2015).

Methods of data analysis

Data were manipulated for descriptive and inferential statistical analysis. Descriptive statistics such as mean ± standard deviation (SD) and range were used to summarize data. Inferential statistics observed were analysis of variance to identify significant variations, t-test to test for variation between seasons and time of monitoring and Pearson correlation matrix to assess the relationships among monitored parameters during the different seasons at both 0.01 and 0.05 confidence levels.

RESULTS

Agricultural activities across the FS

In terms of land area the FS are in this order Ado-Odo > Ibiade > Ago-Iwoye = Sawonjo > Ikenne >Ajegunle > Coker. The Coker FS, which has the least land area, has the highest number of settlers. Ado-Odo, Sawonjo and Coker FS deal majorly in crops especially cassava and other staple crops. The settlers in Ado-Odo and Ikenne FS also deal with cash and tree crops like cocoa, rubber and timber. Palm oil production is common at Ado-Odo, Sawonjo and the largest scale is at Ibiade. Considering animal production, the largest scale of poultry production is at Ikenne, while the largest piggery production is at Ajegunle and small scale piggery is at Ago-Iwoye.

Gaseous pollutants levels

The mean values for gaseous pollutants across the FS are presented in Table 2. The highest concentrations for VOCs (48.67±19.05 ppm) and NH_3 (0.44±0.27 ppm) were observed at Ikenne, for NO_2 (0.13±0.24 ppm) at Ajegunle, CO_2 (4266±1176.85 ppm) and SO_2 (0.02±0.08 ppm) at Sawonjo, and for CO (21.5±3.93 ppm) was at Ibiade. The maximum limits of FEPA (1991) for VOCs, and WHO (2005) for CO, and ASHRAE (2010) for CO_2, were exceeded at all the sampled locations. However, only Ikenne exceeded the limit of FEPA (1991) for NH_3. There are significant variations among the values recorded across the locations at different sites of monitoring for VOCs at $p < 0.05$. The seasonal levels of gaseous pollutants (Table 3) shows that the highest for VOCs, CO, and CO_2 were observed during the wet season while the highest NH_3 was recorded during the dry season. It was also noted that there were significant variations ($p > 0.05$) in the means of VOCs, CO_2, O_3 and fungi across the season. Table 4 shows the concentration of pollutants between the time of monitoring. VOCs, NH_3, and NO_2 displayed the highest values in the morning while CO and CO_2 displayed the highest in the evening. A significant difference was observed only in the means of O_3.

PM pollutants levels

The highest particulates levels across the FS (Table 2) for TSP (47.05±24.09 µg/m3) was at Ikenne, while for PM_{10} (18.31±12.6 µg/m3) and $PM_{2.5}$ (17.43±8.6 ppm) were at Coker. There are significant variations among the values recorded across the locations at different sites of monitoring for TSP, PM_{10}, $PM_{2.5}$ at $p < 0.05$. Table 3 shows that the highest particulate matter levels were observed during the dry season. Besides, the temporal concentrations of PM (Table 4) shows that TSP and $PM_{2.5}$ displayed the highest in the evening while PM_{10} had the highest in the morning. There was no significant temporal variation among the average values of particulate matter measurements. Tables 5 and 6 present the relationships among the parameters during the wet and dry seasons, respectively. The associations observed during the dry season were significant and positive but low. The strong positive and significant correlations were among TSP and PM_{10} (r^2 = 0.822; p<0.01) and TSP and $PM_{2.5}$ ((r^2 = 0.909; p<0.01), TSP and Bacteria((r^2 = 0.310; p<0.01) during the dry season.

Bioaerosol pollutants levels

The highest Bacteria (225.01±1.27 CFU/m3), and fungi (1282.38±1.27 CFU/m3) were recorded at Ikenne (Table 2); also, all the locations had bacteria and fungi loads above the threshold of AIHA (2001) of 500 cfu/m3. There were significant differences in the mean values of fungi across the FS at $p < 0.05$. The highest bacteria and fungi were observed during the wet season (Table 3). There are significant seasonal variations among the mean values recorded in fungi load at $p < 0.05$. Table 4 shows that bacteria and fungi displayed the highest in the evening. There was no significant temporal difference observed in the mean bioaerosol load. Figures 2 - 4 show a directly proportional relationship among particulate components and bio-aerosol load. In other words, the higher the concentration of TSP, PM_{10} and $PM_{2.5}$, the higher the bacteria and fungal load.

Table 1: Major crops and activities in FS

Local Govt	**FS**	Observation and Information
Ado-Odo	Ado-Odo	The Ado-Odo FS is situated within the Ado-Odo/Ota Local Government (LG) on 6°41'N 3°41'E. This FS is the largest with about 3190 hectares of land and about 100 houses. The settlers' deal majorly in crop production such as cocoa, kola nut, palm oil, cassava, timber, maize and vegetables with small scale animal production.
Ikenne	Ikenne	The Ikenne FS is situated within the Ikenne LG on 6° 52'N 3°43'E. This FS has about 835 hectares of land and about 22 houses. The settlers' deal in poultry production on a very large scale and rubber plantation.
Ago-Iwoye	Ago-Iwoye	The Ago-Iwoye FS is situated within the Ijebu North LG on 6°57'N 4°00'E. This FS has about 1508 hectares of land and about 52 houses. The settlers' deal in large scale Cassava production with medium-scale poultry and piggery production.
Yewa North	Sawonjo	The Sawonjo FS is situated within the Yewa North LG on 7°14'N 3°02'E. This FS has about 1508 hectares of land and about 62 houses. The settlers' deal in large scale Cassava production with medium scale palm oil production.
Ogun Waterside	Ibiade	The Ibiade FS is situated within the Ogun Waterside LG on 7°00'N 3°35'E. The LG is a coastal and boundary community. This FS has about 1600 hectares of land and about 35 houses. The settlers' deal in large scale cassava and other seasonal crops with extremely large scale palm oil production.
Abeokuta South	Ajegunle	The Ajegunle FS is situated within the Abeokuta Soth LG on 7°9'39"N 3°20'54"E. This FS has about 497 hectares of land and about 63 houses. The settlers' deal in large scale cassava and other seasonal crops with large scale piggery.
Ifo	Coker	The Coker FS is situated within the Ifo LG on 6°49'N 3°12'E. This FS has about 473 hectares of land and about 120 houses. The settlers' deal in large scale Cassava and other seasonal crops.

Table 2: Concentrations of Monitored Pollutants across the FS.

Location	VOCs (ppm)	NH_3 (ppm)	CO (ppm)	CO_2 (ppm)	O_3 (ppm)	NO_2 (ppm)	SO_2 (ppm)	TSP (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	Bacteria (cfu/m³)	Fungi (cfu/m³)
Ado-Odo	20.8±10.53	0.12±0.31	18.08±4.87	3690.05±1523.2	0.01±0.02	0.06±0.17	<0.01	22.72±13.06	14.15±9.77	11.11±6.53	664.52±1.11	642.68±1.11
Ikenne	48.67±19.05	0.44±0.27	18±7.78	4143.5±444.2	0.01±0.01	0.06±0.14	<0.01	47.05±24.09	16.07±16.84	12.11±13.12	2255.01±1.27	1282.38±1.27
Ago-Iwoye	44.16±11.82	0.14±0.24	17.95±6.65	3562.15±1200.85	<0.01	0.09±0.19	0.01±0.02	20.72±9.28	12.8±11.02	12.76±5.86	971.89±1.16	987.46±1.16
Sawonjo	28.14±13.91	<0.01	19.88±3.46	4266±1176.85	<0.01	<0.01	0.02±0.08	22.14±10.02	10.8±7.05	9.55±3.94	571.56±1.15	771.93±1.15
Ibiade	36.34±19.5	0.01±0.03	21.5±3.93	4194.44±1534.81	<0.01	<0.01	0.01±0.05	22.75±9.21	13.44±7.18	13.38±7.79	548.98±1.18	704.97±1.18
Ajegunle	40.26±19.98	0.15±0.24	17.21±4.92	4011.13±730.7	0.01±0.02	0.13±0.24	0±0.02	27.84±23.33	12.87±14.4	12.42±10.5	667.31±1.15	525.68±1.15
Coker	48.1±4.6	0.02±0.07	19.1±3.87	3938.44±811.59	<0.01	0.02±0.07	0.01±0.08	33.49±22.18	18.31±12.6	17.43±8.6	856.65±1.1	593.92±1.1
FEPA (1991)	3	0.28										
ASHRAE (2010)				1000								
WHO (2005)			10		0.1				50	25		
WHO (2002)						0.04						
WHO (2000)							0.02					
AIHA (2001)											<500	<500
P value	<0.0001	0.5855	0.4238	0.1266	0.1713	0.4506	0.8895	0.0003	<0.0001	0.0003	0.382	0.0336

$p < 0.05$; Concentration = Mean±standard deviation

Table 3: Seasonal concentrations of monitored pollutants

Season	VOCs (ppm)	NH_3 (ppm)	CO (ppm)	CO_2 (ppm)	O_3 (ppm)	NO_2 (ppm)	SO_2 (ppm)	TSP (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	Bacteria (cfu/m³)	Fungi (cfu/m³)
Wet	36.38±17.93	0.1±0.24	17.78±6.33	3964.52±1368.52	0.01±0.01	0.04±0.16	0.01±0.06	24.02±20.29	9.28±6.38	8.3±6.63	802.15±1.08	800.87±1.08
Dry	34.69±14.59	0.05±0.16	17±4.67	3822.69±701.04	<0.01	0.04±0.11	<0.01	24.44±15.89	16.56±9.69	15.31±15.2	651.22±1.08	594.04±1.08
FEPA (1991)	3	0.28										
ASHRAE (2010)				1000								
WHO (2005)			10		0.1				50	25		
WHO (2002)						0.04						
WHO (2000)							0.02					
AIHA (2001)											<500	<500
p value	0.002	0.6506	0.1063	0.0035	0.0181	0.4461	0.9126	0.7425	0.5813	0.1017	0.167	0.0143

$p < 0.05$; Concentration = Mean±standard deviation

Table 4: Temporal concentrations of monitored pollutants

Time	VOCs (ppm)	NH_3 (ppm)	CO (ppm)	CO_2 (ppm)	O_3 (ppm)	NO_2 (ppm)	SO_2 (ppm)	TSP (µg/m³)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	Bacteria (cfu/m³)	Fungi (cfu/m³)
Morning	35.71±15.22	0.09±0.25	17.02±5.37	3827.46±1130.41	< 0.01	0.05±0.15	< 0.01	24.2±17.66	12.58±9.72	12.16±11.99	575.44±0.04	599.7911
Evening	35.36±17.44	0.05±0.14	17.76±5.75	3959.75±1042.98	< 0.01	0.03±0.11	0.01±0.06	24.27±18.78	12.43±12.1	12.28±8.82	616.60±0.04	650.0698
FEPA (1991)	3	0.28										
ASHRAE (2010)				1000								
WHO (2005)			10		0.1				50	25		
WHO (2002)						0.04						
WHO (2000)							0.02					
AIHA (2001)											<500	<500
p value	0.0733	0.0796	0.4055	0.5812	0.0404	0.7306	0.5502	0.2325	0.1781	0.8558	0.33	0.93

$p < 0.05$; Concentration = Mean±standard deviation

Table 5: Correlation matrix among measured parameters in the FS(s) during the wet season

Parameters	Humidity	VOCs	NH_3	CO	CO_2	O_3	NO_2	SO_2	CH_4	TSP	PM_{10}	$PM_{2.5}$	Bacteria	Fungi
Temp	0.00	0.13	0.12	0.02	0.04	0.17	0.09	-0.15	-0.02	0.246*	0.12	0.19	0.03	0.11
Humidity	1	0.225*	0.12	0.12	-0.11	-0.226*	0.03	0.19	0.02	-0.04	-0.14	0.00	0.20	-0.17
VOCs		1	0.00	0.11	0.263*	0.15	0.230*	0.06	0.14	0.213*	0.246*	0.04	0.14	-0.08
NH_3			1	0.10	-0.18	0.04	0.405**	0.565**	-0.03	-0.14	-0.290**	-0.16	0.10	-0.12
CO				1	-0.13	-0.05	0.12	-0.04	-0.01	0.01	-0.03	0.05	-0.10	-0.225*
CO_2					1	0.08	-0.01	-0.270*	0.243*	0.13	0.18	0.05	-0.10	-0.01
O_3						1	-0.09	0.00	-0.04	0.276**	0.362**	-0.07	-0.12	0.15
NO_2							1	0.441**	0.20	-0.12	-0.11	-0.10	-0.03	-0.11
SO_2								1	-0.01	-0.19	-0.17	-0.19	-0.03	-0.08
CH_4									1	0.08	0.08	0.11	-0.10	-0.11
TSP										1	0.780**	0.814**	0.08	0.04
PM_{10}											1	0.526**	-0.08	0.14
$PM_{2.5}$												1	0.20	-0.17
Bacteria													1	0.04
Fungi														1

* $p < 0.05$; ** $p < 0.01$

Table 6: Correlation matrix among measured parameters in the FS(s) during the dry season

Parameters	Humidity	VOCs	NH_3	CO	CO_2	O_3	NO_2	SO_2	TSP	PM_{10}	$PM_{2.5}$	Bacteria	Fungi
Temp	-0.16	0.04	-0.03	0.09	0.17	0.01	0.14	-0.05	-0.13	-0.18	-0.11	-0.14	-0.07
Humidity	1	0.06	0.09	0.410**	-0.11	-0.09	0.07	0.02	0.01	-0.11	-0.05	0.15	0.03
VOCs		1	0.14	-0.11	0.237*	0.10	0.19	-0.14	0.20	0.06	0.12	0.15	-0.14
NH_3			1	-0.14	0.19	0.02	0.15	-0.06	-0.08	-0.20	-0.19	0.289**	0.08
CO				1	-0.04	0.04	-0.252*	0.03	-0.07	0.00	-0.06	-0.18	-0.02
CO_2					1	0.05	0.01	-0.10	0.10	0.00	-0.05	0.07	-0.10
O_3						1	0.10	0.02	0.06	0.09	-0.02	-0.07	-0.04
NO_2							1	-0.06	0.12	0.02	0.12	0.18	-0.07
SO_2								1	-0.12	-0.10	-0.11	-0.08	0.06
TSP									1	0.822**	0.909**	0.310**	-0.08
PM_{10}										1	0.799**	0.13	-0.07
$PM_{2.5}$											1	0.327**	-0.01
Bacteria												1	0.222*
Fungi													1

* $p < 0.05$; ** $p < 0.01$

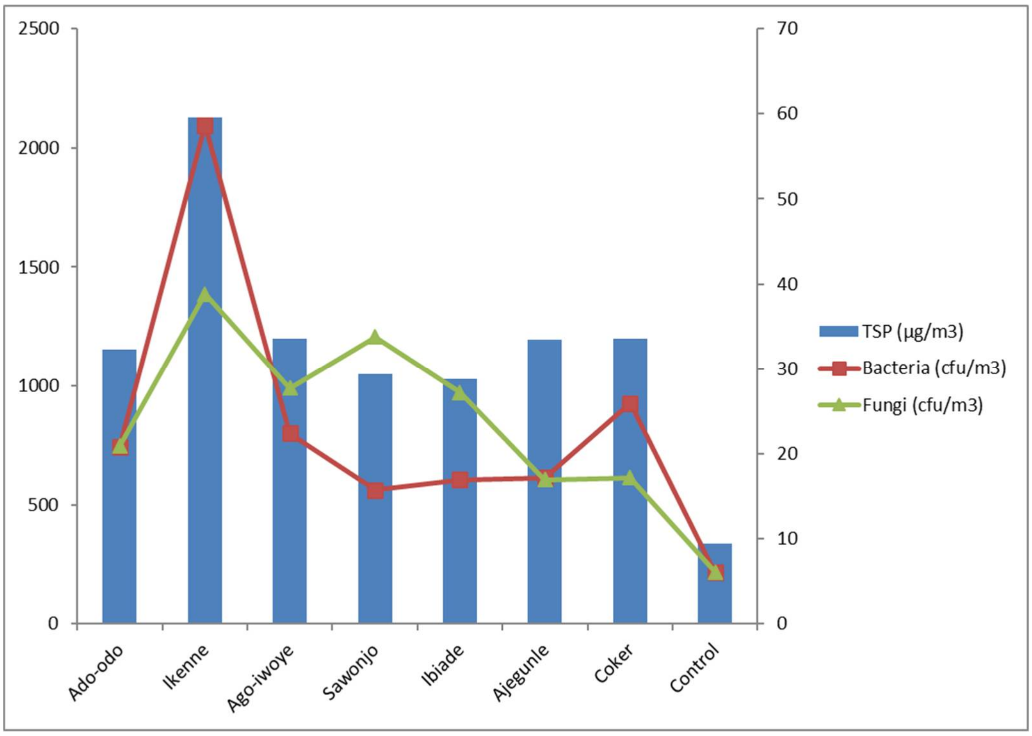

Fig. 2: Relationship among concentration of TSP, bacterial and fungal load

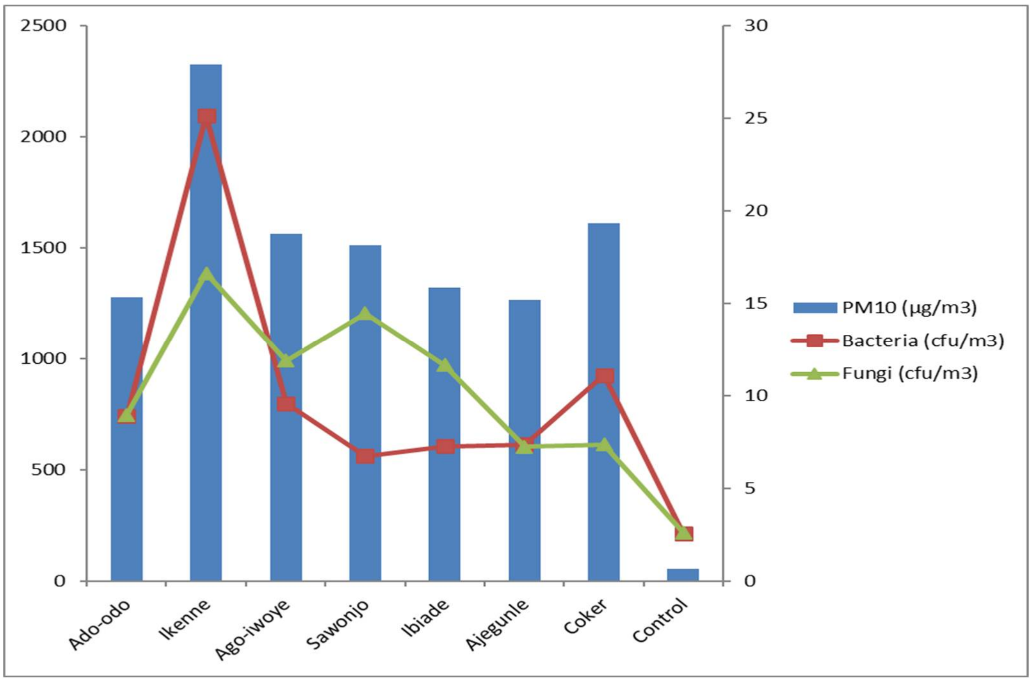

Fig. 3: Relationship among concentration of PM_{10}, bacterial and fungal load

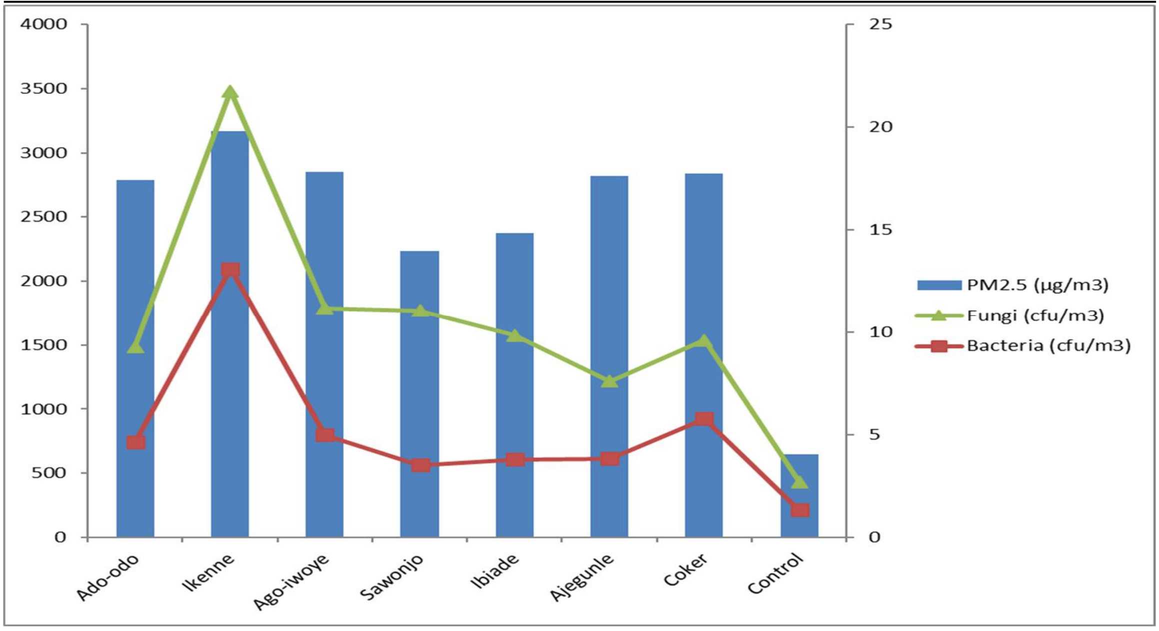

Fig. 4: Relationship among concentration of $PM_{2.5}$, bacterial and fungal load

DISCUSSION

The various sites have peculiarities in location, the predominant agricultural activities and different kinds of emissions observed. Ajegunle FS is situated close to the express road with a nearby quarry site and heavy-duty trucks in and out of the quarry sites increasing the vehicular gaseous emission in the FS. Important gases produced from vehicular emissions are VOCs, TSP, SO_2, NO_2 and CO, which can have adverse effects on the exposed population (Ingle *et al*., 2005). VOCs are critical surface ozone precursors (Li *et al*., 2017). Ibiade is characterized by large scale palm oil productions that require burning of wood for fuel. Wood burning is a dirty cooking energy source which produces elevated concentrations of CO_2, NO_2 and CO in the indoor and outdoor environment. According to Ohimain and Izah (2013), palm oil production requires boiling and digestion activities. Ibiade being a border town and very close to waterfronts, has the tendency of increased humidity which support the growth of fungi as corroborated by the findings of Afzal *et al*. (2004).

Ikenne is a very small FS and highly congested, in addition to storage of poultry feed indoor and nearby scattered animal houses. These observations further justified the elevated concentrations of TSP, PM_{10} and $PM_{2.5}$ which is in line with the studies of Xu *et al*. (2016) in China; Winkel *et al*. (2016) in the Netherlands and Mostafa *et al*. (2016) in Germany. High NH_3 concentrations were also reported outdoors, possibly due to large -scale animal husbandry, which is known to account for most of the total emissions of ammonia. The highest level of pollutions from the agricultural sector is by methane, ammonia and carbon dioxide (Harizanova-Bartos and Zornitsa Stoyanova, 2018). Ammonia is released majorly from the birds through the excretion of unused nitrogen in the form of 80% uric acid, 10% ammonia, and 5% urea (Karimi, 2017). Ammonia gas reacts with moisture to form a simple, corrosive solution called ammonium that can damage birds and humans by corroding the respiratory tract of chickens, thereby paralyzing or even destroying the epithelial cells. Under such conditions, the cilia can not clear the mucus on the mucosal surface of the trachea and thus trapping bacteria, entering the lungs or air sacs and causing infection (Karimi, 2017). High bacteria load in Ikenne is probably as a result of the intense animal husbandry as corroborated by Zucker *et al*. (2000) who reported diverse bacteria isolated in animal houses; and presence of animal pets especially dogs increase the bacterial load (Dunn *et al*., 2013). According to Harizanova-Bartos and Zornitsa Stoyanova (2018), the biggest environmental polluters in livestock husbandry are cattle-breeding, buffalo-breeding, the pig sector, sheep and goat farming. It appears that three locations (Ikenne, Ago-Iwoye and Ajegunle) where extensive and large scale animal husbandry is predominant showed increased outdoor bacterial concentration, while fungal concentration reduced in the outdoor relative to indoor. In the urban areas, the presence of factors of globalization; industrialization and transportation have been studied extensively and proven as the significant sources of air pollutants (Power *et al.,* 2014). These factors are relatively absent in rural areas, although there exist other activities which tend to emit and increase the ambient concentration of air pollutants (Oyebanji *et al*., 2016). The global health burden from air pollutions falls largely on the rural populace (Karambelas *et al.,* 2018) where agriculture is the predominant occupation.

Higher concentrations of CO_2 exceeding the ASHRAE (2010) permissible limit across all monitored locations, seasons, time and site (indoor/outdoor) is probably due to indirect emissions from deforestation and *land* cultivation and soil preparation (Gilbert, 2012). CO_2 are likely to impact global climate and the growth, biology, and chemistry and metabolism of plants (Dusenge *et al.,* 2019).

The location-based analysis revealed that CO concentrations at all the farm settlements exceeded that threshold limit. This might not be unconnected to the various household cooking activities (Oyebanji *et al.,* 2013); slashing and burning of unwanted plants (Rohila *et al.,* 2017) and tractors usage (Rashid *et al*., 2013). CO is a noxious gas whose existence affects the levels of other greenhouse gases including carbon dioxide, methane and tropospheric ozone by interacting easily with the hydroxyl radical (OH) to form stronger greenhouse gas CO_2).

Considering particulate matter concentration, only Ikenne exceeded the $PM_{2.5}$ threshold limit.

Due to the ability of $PM_{2.5}$ to penetrate unfiltered into the lungs and blood vessels, inhalation of this fine particulate matter can cause severe respiratory disease and heart disease aggravating disease, leading to irreversible DNA mutations, heart attacks and subsequent death (Ojekunle *et al*., 2018). The study by Raaschou-Nielsen et al. (2013) across seventeen European countries showed a significant association between risk for lung cancer, PM_{10} and $PM_{2.5}$.

The relationship recorded among the particulate matter (TSP, PM_{10} and $PM_{2.5}$) and bioaerosols (bacteria and fungi) clearly show that the contents of particles are diverse. Although the pathogenicity of the bacteria and fungi isolated was not determined, Kalisa *et al.* (2019) already ascertained that significant and dominant fractions of airborne PM are bio-aerosols. Similarly, bio-aerosol levels are usually determined by the levels of particulate matter as reported by Grzyb & Lenart-Boroń (2019).

CONCLUSION

This study monitored the ambient concentration of gases, particulates matter and bio-aerosol load within farm settl#ements during the wet and dry seasons respectively, including the morning and evening. The burden of gaseous and particulate pollutants was assessed using potable hand-held active air samplers while bio-aerosols were isolated following gravity settling and standard plate -count procedure. The mean concentrations of VOCs, CO_2, CO, bacteria and fungi across all the sampled locations were above the standard threshold, while only Ikenne exceeded the standards NH_3. There were significant positive relationships among the PM microns monitored and bio-aerosol concentration. The levels of air pollutants varied across the FSs due to the different farming expertise across the settlements. Gaseous pollutants were higher in FS with extensive crop farming and processing while particulate matter and bio-aerosols were relatively higher in FS with extensive animal husbandry and related activities. Farmers should be advised to protect themselves with the use of nose mask against direct inhalation of air pollutants during their daily work. There is a need to reduce burning activities, locate farm produce processing generating air pollutants away from the residences and maintain proper hygiene practices when handling animals.

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