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SPATIAL AND TEMPORAL VARIATION OF VOLATILE ORGANIC COMPOUNDS (VOCS) POLLUTION IN ISOLO INDUSTRIAL AREAS OF LAGOS STATE, SOUTHWESTERN – NIGERIA

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Abstract
Spatial and temporal variations of volatile organic compounds in ambient air in Isolo Industrial Area during May, 2010 to April, 2011 are presented. The results were analysed in other to present information about the detailed nature of air quality situation in the sampled areas. The air samples were collected by passive sampler (ORSA 5). The air samplers were exposed to a height of 1.5 - 2.0 m and sampling was carried out four times a month for a period of 12 months. The adsorbed VOCs were desorbed with carbondisulphide (CS_2) and the solution analysed using Gas Chromatography (GC) fitted with Flame Ionization Detector (FID). The results from analysis of the air samples collected showed that twenty (26) VOCs were captured. There is a significant difference ($P < 0.05$) between the levels of VOCs in Isolo. Despite comparatively higher concentrations of VOCs at the studied sites, there is a significant difference in the spatial distribution. At lower wind speed, the VOCs concentrations tend to increase and become uniformly distributed around the industrial Areas. The temporal distribution shows a decrease in ambient concentrations of VOCs from May to July due to Atmospheric (dilution)/wash down by rain. The results of two-way factor ANOVA analysis of the monthly average of total volatile organic compounds revealed that there is significant difference ($P < 0.05$) in seasonal and temporal variations of TVOC concentrations in the studied areas. The meteorological parameters showed significant correlations with the ambient concentrations of VOCs. The principal component analysis revealed that the major sources of VOCs in Isolo are mainly Anthropogenic and four (4) factors were identified as sources of VOCs in the studied area with Industrial and emissions from traffic dominating.

Key words: *Significant, Pollution, Spatial, Anthropogenic, Temporal*

Introduction

VOCs play an important role in the chemistry of the atmosphere; their role in the formation of photochemical smog and their associated oxidants, degrading air quality and threatening both human health and ecosystem (Molina *et al*., 2007; Ulman and Chilmonczyk, 2007). Studies have shown that VOCs enter the human bloodstream through the following means inhalation, ingestion and through the skin (ATSDR, 2001). The short term adverse effects include conjunctive irritation, nose and throat discomfort, headache and sleeplessness, allergic skin reaction, nausea, fatigue and dizziness. While the long term adverse effects include loss of coordination, leukamia, anaemia, cancer and damage to liver, kidney and central nervous system (Kim *et al*., 2001; Eljarrat and Barcelo, 2003; Kerbachi *et al*., 2006). Vehicular emissions apart from Industrial emissions from the main part of air pollution in Apapa Industrial areas, few studies towards the concentrations of Volatile Organic Compounds (VOCs) have been published in Lagos - state (Okuo *et al*., 2012 a,b). Several researchers have attempted VOCs monitoring studies over different parts of the world considering VOCs increasing importance in environmental issues (Ohura *et al*., 2006; Simona *et al*., 2009; Son *et al*., 2003; Okuo *et al*., 2011). Higher concentrations of VOCs were recorded in the morning and evening with low concentrations in the afternoon in central Seoul (Na *et al*., 2003). Weekdays - Weekends variations of total volatile organic compounds (TVOCs) in atmosphere of Benin City, Southern, Nigeria was determined by Olumayede *et al*., (2011). Except for the difference caused by the variation of temperature, the spatial distribution of emission density remained the same among different seasons (Zhang *et al.*, 2007). Meteorological conditions and photochemical activities cause diurnal, seasonal and annual variations of VOCs concentrations (Na and Kim, 2001; Borton *et al.*, 2002). Silke *et al.* (2010), studied spatial and temporal variation of outdoor and indoor exposure of volatile organic compounds in Greater Cairo concluding that Greater Cairo is burdened by BTEX. The spatial and temporal distribution of VOCs concentration in Ikeja/Apapa Industrial areas was found to be dependent mainly on industrial activities such as industrial solvent usage, petrochemical processes, storage and distribution of chemicals, combustion processes, vehicular/petroleum product emission and meteorological factor such as wind speed, direction of wind, humidity, rainfall and temperature (Ojiodu, 2013; Ojiodu *et al.*, 2013).

The seasonal variation of measured concentrations of VOCs in certain periods (eg. summer months) have to be adjusted for other periods using appropriate cycle factors (Schlink *et al.*, 2004). The spatial and temporal distribution of VOCs concentration Science-based Industrial Park (SBIP) was dependent mainly on wind speed, wind direction and industrial emissions from the Park (Huang *et al.*, 2005). The objective of this present study is to investigate the seasonal and temporal variations of VOCs pollution and the possible effects of and meteorological conditions in the studied area.

Study Area

Lagos state with a population of 18million compared with 8-9 million in London, 8million in New-York and 7million in Paris, is one of the world's mega-cities. It is the most populous and industrialized city in Africa and its population far exceed the entire population of some countries. It is the nation's economic nerve centre with over 2000 industries. Currently, over 200,000 vehicles are registered annually in Lagos State (NPC, 2009; LASG, 2006). Isolo industrial area is situated at Oshodi-Isolo Local Government area of Lagos state. It is in Ikeja division of Lagos state. Isolo industrial area is located on longitude 6.31^0N and latitude 3.19^0E. Its population which the Local Government area estimated at 521,509 people according to the 2006 final census results (NPC, 2009). Conspicuous in these area are various types of industries which include textile, pharmaceutical, soap and detergent, food and beverage, paint, printing and publishing etc. There are also clusters of filling stations, commercial stores, eateries, Motor parks, official and residential house. The land-use pattern of Isolo industrial area is mixed, residential and industrial. Therefore, there is need to investigate ambient air pollution by volatile organic compounds in Isolo industrial area of Lagos state. Volatile Organic Compounds are commonly encountered by people as they go about their daily routine. This study was conducted in Isolo industrial area of Lagos state, namely Abimbola Street, Johnson Wax, IIasamaja Market, Chesebrough way, Isolo-Apapa Road, IIe-iwe meta, Rotary Road, Isolo Road, Afprint, and Aswani Market. Isolo lies within the tropical rainforest region with two distinct seasons: wet and dry seasons. The temperature throughout the year ranges between 21^0C and 30^0C. Humidity is relatively high while the rainfall ranges between 150mm - 200mm. The wind speed recorded during the study ranged between 3.20 - 6.00 ms^{-1}.

Methodology

Sampling Locations

This study was conducted in Isolo Industrial area of Lagos state. Isolo lies within the tropical rainforest region with two distinct seasons: wet and dry seasons. The temperature throughout the year ranges between 21^0C and 30^0C. Humidity is relatively high while the rainfall ranges between 150mm-200mm. The wind speed recorded during the study ranged between 3.20 - 6.00 ms^{-1}.

Selection of Sampling Site

The samples were collected at ten sites within the study area during the wet and dry seasons. The sites were carefully chosen based on the following criteria: Cost of equipment, accessibility to the locations, freedom from any obstacle to free flow of air in the vicinity and security of the sampler. The locations (sites) were chosen to reflect activities in the areas. The geo-referencing was carried out by using GARMIN GPS MAP 76S.

Sample Collection and Analytical Methods

The sample collection and the Analytical methods were based Ojiodu *et al.* (2013). Two-way Analysis of Variance (ANOVA) statistical test was used to evaluate significance of the differences in means; we use correlation coefficient (r^2). Sources of emission were determined using correlation coefficient ($p< 0.05$) and the factor analysis (Principal Component Analysis) (SPSS, 2007).

Factor Analysis

The Principal Component Analysis (PCA) are the primary factor analysis techniques that uses eigen value to apportion data sets to identify emission sources, chemical interaction on meteorological phenomenon depending on the data sets that have been submitted to PCA. PCA is use to classify variables into groups that can then be associated with factors that contribute to pollutant levels at receptors. Four factors were identified as contributing to the measured values in Isolo industrial area. The first (FI), second (F2), third (F3) and fourth (F4) factors accounted for 40.52, 25.26, 15.24 and 13.16% of the total variance. **F1:** This factor is highly loaded in ethylbenzene, isopropylbenzene, naphthalene, tuolene, trichloroethane and chloroform. These chemicals are used in cosmetics and paint industries and in the area. They are also released from petroleum products from petrol stations located in the area. Therefore, factor 1 is attributed to emissions from industrial solvent usage and petroleum products. **F2:** Ethylbenzene, ethanol, chlorobenene and xylene is loaded in factor 2. These compounds are released from vehicle exhaust and petroleum products from petrol stations in the vicinity of the studied area. Factor 2 suggests vehicular and petroleum products emission. **F3:** Factor 3 is highly loaded in ethanol, acetone and chloroform. These compounds are used as solvent in textile and paint industries in the study area. Therefore, factor 3 is attributed to industrial solvent usage. **F4:** Tetrachloroethane and trichlorofloromethane are loaded in factor 4. These are solvents used in paint and textile industries in the study area. They are also released from refrigerator and air conditioner workshops in the area. Factor 4 is due to industrial solvent usage and evaporative emission.

Results and Discussion

Twenty-Six (26) VOCs were captured in each of the ten sites in Isolo industrial areas during the wet and dry seasons (Table 1). The VOCs were classified thus: aromatics, halogenated, esters, ketones, alcohols, ethers, dienes, and nitriles.

There is an increase in the VOCs concentration from November to December, 2011 (dry season). This may be due to the fact that the period is characterized by high human and industrial activities. There is a progressive increase in concentration from the month of August to December, 2012. Conversely, there is a decrease in VOCs concentration from May to July, 2012. Generally, the month of July has the lowest VOCs concentrations (Table 2).This may be due to wash down by rain during the wet season. The levels of VOCs obtained in the studied areas in dry season is 3 to 6 times higher than the wet season (Table 2). The dry/wet ratio of the measured TVOC shows high level of VOCs in the dry seasons (Figure 1). The high ratio obtained is an indication that more of the VOCs were released in the studied areas during the dry season, this may also be attributed to a greater industrial activities such as solvent usage, petrochemical processes, storage and distribution of chemicals, combustion processes, vehicular exhaust and petroleum product emission, emissions from waste dump and evaporative sources such as from dry cleaning shops, refrigerator and air conditioner workshops, fuel filling stations and hawkers of cloths, foot wears, cosmetics etc . Similarly, high levels of VOCs were recorded with low wind speed (Table 3). In dry season, Companies productivity is high and the season is characterized by more human activities leading to an increase in VOC levels. In the wet season, VOC levels are low due to dilution of the Atmospheric air. There is a strong positive correlation coefficient ($r^2 = 0.958$) between the concentration of VOCs in the dry and wet seasons. The specific site monthly average of the total volatile organic compound observed in the different sampling sites of the industrial area reveal significant seasonal variability ($P< 0.05$) with high values obtained during the dry seasons and low in the wet seasons.

Table 1 Monthly Measured Mean Concentration of VOCs at Isolo Industrial Area (µg/m^3) n = 10

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AROMATIC VOCs	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
BENZENE	10.38 ± 0.87	10.42 ± 0.05	10.39 ± 0.06	9.71 ± 0.12	3.46±0.07	3.44±0.06	3.30±0.06	3.42±0.06	3.43±0.06	3.45±0.06	10.34 ± 0.02	10.39 ± 0.02
ETHYL BENZENE	12.53 ± 0.08	12.73 ± 0.11	12.81 ± 0.07	10.33 ± 0.13	3.58±0.05	3.53±0.04	3.47±0.04	3.48±0.04	3.52±0.04	3.57±0.04	12.56 ± 0.02	12.54 ± 0.05
ISOPROPYLBENZENE	14.23 ± 2.96	14.69 ± 0.02	14.62 ± 0.09	12.52 ± 0.27	3.95±0.03	3.91±0.03	3.85±0.03	3.88±0.03	3.92±0.03	3.95±0.03	14.76 ± 0.01	14.63 ± 0.06
NAPHTHALENE	11.33 ± 0.03	11.27 ± 0.03	11.22 ± 0.03	9.99 ± 0.36	3.39±0.05	3.33±0.04	3.25±0.04	3.30±0.04	3.33±0.04	3.36±0.04	11.17 ± 0.02	11.30 ± 0.10
n-BUTYLBENZENE	15.29 ± 1.61	15.29 ± 0.04	15.21 ± 0.07	13 04 ± 0.14	3.74± 0.67	3.73±3.67	3.62±3.67	3.64±3.67	3.67±3.67	3.69±3.67	15.24 ± 0.02	15.31 ± 0.03
n-PROPYLBENZENE	12.15 ± 0.08	12.15 ± 0.06	12.00 ± 0.05	10.77 ± 0.18	2.94±0.90	2.91±2.90	2.86±2.90	2.88±2.90	2.90±2.90	2.93±2.90	12.36 ± 0.05	12.38 ± 0.07
TOLUENE	10.13 ± 1.52	10.09 ± 0.04	10.12 ± 0.06	8.67 ± 0.29	4.10±0.04	4.08±0.04	4.00±0.03	4.01±0.03	4.02±0.03	4.05±0.03	9.69 ± 0.13	9.89 ± 0.31
m+P-XYLENE	22.50 ± 0.01	22.54 ± 3.99	22.50 ± 0.03	12.08 ± 0.08	8.90±0.05	8.88±0.05	8.74±0.05	8.80±0.05	8.86±0.05	8.87±0.05	22.44 ± 0.02	22.49 ± 0.02
o-XYLENE	12.63 ± 0.01	12.69 ± 0.04	12. 67 ± 0.04	10.40 ± 0.26	5.31±0.04	5.28±0.04	5.23±0.03	5.25±0.03	5.26±0.03	5.27±0.03	12.71 ± 0.02	12.74 ± 0.02
HALOGENATED VOCs												
BROMIDES												
BROMOMETHANE	8.99 ± 0.01	9.01 ± 0.03	8.90 ± 0.05	6.24 ± 0.20	1.56±0.10	1.54±0.10	1.38±0.10	1.40±0.10	1.42±0.10	1.47±0.10	8.48 ± 0.04	8.76 ± 0.30
BROMOFORM	13.67 ± 0.10	13.86 ± 0.03	13.73 ± 0.05	11.14 ± 0.24	2.69±0.07	2.68±0.07	2.52±0.07	2.55±0.07	2.62±0.06	2.67±0.06	13.55 ± 0.02	13.61 ± 0.03
CHLORIDES												
CHLOROBENZENE	13.43 ± 0.51	13.47 ± 0.06	13.43 ± 0.04	12.07 ± 0.23	5.31±0.03	5.28±0.03	5.21±0.03	5.23±0.03	5.25±0.02	5.26±0.02	13.42 ± 0.02	13.47 ± 0.01
CHLOROFORM	12.14 ± 1.07	12.13 ± 0.01	12.08 ± 0.03	10.77 ± 0.29	3.07±0.04	3.04±0.04	2.96±0.03	3.02±0.03	3.04±0.03	3.05±0.03	12.14 ± 0.00	12.16 ± 0.01
CARBONTETRACHLORIDE	13.56 ± 1.10	13.56 ± 0.03	13.53 ± 0.05	11.11 ± 0.17	4.44±0.07	4.41±0.06	4.28±0.06	4.30±0.06	4.39±0.06	4.40±0.06	13.68 ± 0.02	13.72 ± 0.05
METHYLENE CHLORIDE	11.17 ± 2.08	11.25 ± 0.03	11.14 ± 0.02	10.55 ± 0.31	2.01±0.02	1.96±0.02	2.00±0.02	2.00±0.02	2.00±0.02	2.01±0.02	11.12 ± 0.01	11.18 ± 0.04
TRICHLOROETHANE	10.09 ± 1.08	10.15 ± 0.11	10.23 ± 0.07	9.70 ± 0.20	2.00±0.01	1.99±0.01	1.94±0.01	1.95±0.01	1.98±0.01	1.99±0.01	10.34 ± 0.06	10.36 ± 0.11
TRICHLOROFLOROMETHANE	12.36 ± 1.15	12.27 ± 0.09	12.29 ± 0.07	10.68 ± 0.47	2.84±0.03	2.79±0.03	2.76±0.03	2.79±0.03	2.82±0.03	2.83±0.03	12.33 ± 0.01	12.36 ± 0.02
1,2-DICHLOROPROPANE	12.18 ± 5.17	12.16 ± 0.01	12.10 ± 0.03	11.58 ± 0.36	2.03±0.03	2.01±0.03	1.94±0.03	1.96±0.03	1.98±0.03	2.00±0.03	12.17 ± 0.01	12.29 ± 0.02
2,2-DICHLOROPROPANE	13.17 ± 0.27	13.18 ± 0.02	13.11 ± 0.03	9.88 ± 0.22	2.18±0.05	2.16±0.05	2.04±0.04	2.06±0.04	2.09±0.04	2.10±0.04	13.17 ± 0.01	13.21 ± 0.01
TETRACHLOROETHANE	11.82 ± 0.03	11.91 ± 0.06	11.94 ± 0.03	10.31 ± 0.22	2.81±0.05	2.76±0.04	2.69±0.04	2.72±0.04	2.74±0.04	2.76±0.04	11.61 ± 0.03	11.69 ± 0.18
KETONE VOCs												
ACETONE	12.01 ± 1.49	11.95 ± 0.34	11.65 ± 0.03	9.63 ± 0.24	5.41±0.06	5.39±0.06	5.23±0.06	5.26±0.06	5.29±0.06	5.34±0.06	11.55 ± 0.03	11.62 ± 0.02
4-METHYL-2-PENTANONE	12.15 ± 0.72	12.19 ± 0.06	12.19 ± 0.14	10.57 ± 0.27	1.18±0.03	1.16±0.03	1.09±0.03	1.10±0.03	1.12±0.03	1.16±0.03	11.95 ± 0.42	11.89 ± 0.46
ESTER VOC												
ISOPROPYLACETATE	8.08 ± 2.69	8.15 ± 0.10	8.14 ± 0.03	6.74 ± 0.26	3.94±0.07	3.91±0.07	3.69±0.07	3.79±0.07	3.86±0.07	3.92±0.07	8.47 ± 0.06	8.43 ± 0.08
ALCOHOL VOC												
ETHANOL	12.06 ± 0.76	12.05 ± 0.01	11.97 ± 0.03	9.67 ± 0.27	4.56±0.04	4.51±0.04	4.44±0.04	4.51±0.04	4.52±0.04	4.58±0.04	12.15 ± 0.07	12.07 ± 0.00
ETHER VOC												
TETRAHYDROFURAN	7.08 ± 1.53	7.09 ± 0.01	7.03 ± 0.02	5.71 ± 0.21	2.28±0.01	2.27±0.01	2.23±0.01	2.25±0.01	2.26±0.01	2.28±0.01	7.08 ± 0.00	7.10 ± 0.05

Table 2: Measured Mean Concentration of VOCs at Isolo Industrial Area During Dry and Wet Season ($\mu g/m^3$) n = 10

	DRY SEASON				WET SEASON			
	MEAN	STD	MIN	MAX	MEAN	STD	MIN	MAX.
AROMATIC VOCs								
BENZENE	10.39	0.168	10.03	10.65	3.41	0.08	ND	3.46
ETHYL BENZENE	12.62	0.22	12.27	12.92	3.53	0.05	ND	3.58
ISOPROPYLBENZENE	14.51	0.29	14.00	14.97	3.90	0.03	3.85	3.95
NAPHTHALENE	11.30	0.23	11.16	11.86	3.32	0.05	3.25	3.39
n-BUTYLBENZENE	15.31	0.158	15.19	15.66	3.68	0.04	3.62	3.74
n-PROPYLBENZENE	12.24	0.11	12.10	12.39	2.90	0.03	2.86	2.94
TOLUENE	9.96	0.141	9.76	10.27	4.05	0.04	4.01	4.11
m+ p-XYLENE	22.39	0.16	22.17	22.90	8.83	0.05	8.74	8.90
o-XYLENE	12.71	0.23	12.14	12.97	5.23	0.04	5.16	5.28
HALOGENATED VOCs								
BROMIDES								
BROMOMETHANE	8.801	0.14	8.51	8.94	1.47	0.10	1.27	1.56
BROMOFORM	13.65	0.17	13.35	13.97	2.60	0.07	2.51	2.69
CHLORIDES								
CHLOROBENZENE	13.42	0.11	13.21	13.60	5.26	0.03	5.21	5.31
CHLOROFORM	12.15	0.02	12.10	12.19	3.01	0.04	2.96	3.07
CARBONTETRACHLORIDE	13.61	0.15	13.34	13.85	4.37	0.07	4.27	4.44
METHYLENE CHLORIDE	11.181	0.11	11.05	11.41	1.99	0.02	1.96	2.01
TRICHLOROETHANE	10.13	0.07	10.05	10.30	1.97	0.03	1.94	1.99
TRICHLOROFLOROMETHANE	12.33	0.36	11.89	12.86	2.80	0.03	2.76	2.84
1,2-DICHLOROPROPANE	12.15	0.03	12.11	12.22	1.98	0.03	1.94	2.03
2,2-DICHLOROPROPANE	13.19	0.03	13.14	13.23	2.10	0.05	2.04	2.18
TETRACHLOROETHANE	11.73	0.29	11.15	11.99	2.75	0.05	2.69	2.84
KETONE VOCs								
ACETONE	11.52	0.15	11.16	11.61	5.33	0.06	5.23	5.41
4-METHYL-2-PENTANONE	11.88	0.30	11.11	12.18	1.14	0.03	1.09	1.18
ESTER VOC								
ISOPROPYLACETATE	8.33	0.18	8.08	8.61	3.864	0.07	3.69	3.94
ALCOHOL VOC								
ETHANOL	12.08	0.04	12.03	12.19	4.51	0.04	4.44	4.58
ETHER VOC								
TETRAHYDROFURAN	7.09	0.03	7.05	7.13	2.26	0.02	2.23	2.28

ND = below the detection limit of the Sampler = $0.001\mu gm^{-3}$

Table 3: Measured TVOCs, Wind Speed, Relative Humidity, Temperature and Rainfall

MONTH	ISOLO	TEMP(^{0}C)	RELATIVE HUMIDITY(%)	WIND SPEEDms^{-1}	RAINFALL(mm)	WIND DIRECTION
May-10	87.68	27.80	86	6.00	159.30	S
Jun-10	86.95	26.30	87	4.50	367.70	S
Jul-10	84.72	25.10	89	4.50	130.80	SW
Aug-10	85.55	25.10	88	5.70	190.60	SW
Sep-10	86.22	26.20	90	4.20	253.70	SW
Oct-10	86.96	26.70	84	3.70	122.80	SW
Nov-10	304.48	27.80	81	3.50	126.70	SW
Dec-10	305.59	28.00	77	3.20	76.70	S
Jan-11	305.13	29.20	61	3.30	38.00	SW
Feb-11	306.28	30.20	72	5.20	52.50	SW
Mar-11	305.00	29.30	77	4.60	69.00	S
Apr-11	253.86	29.20	79	5.50	136.20	S

Source: Nigerian Meterological Agency, 2010/2011

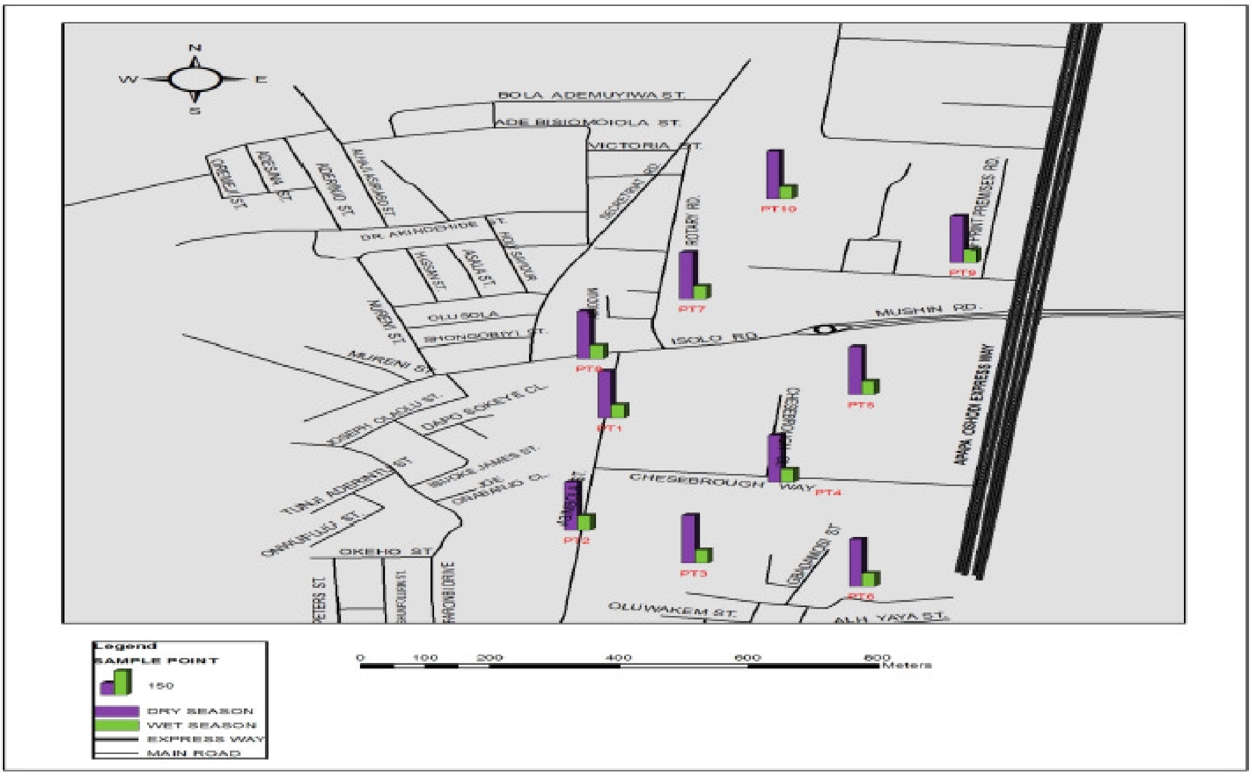

Figure 1 GIS Base - Map of Isolo Industrial Area showing Dry and Wet seasons

The effect of temperature and other meteorological factors such as relative humidity, wind speed and direction were suggested as to playing more significant roles in causing seasonal variation (So and Wang, 2004; Wang *et al.*, 2007). The ambient VOCs in the studied areas were characterized by low wind speed with corresponding high temperature, low humidity and in some cases relatively low rainfall with South-South West (S-SW) wind prevailing (Table 3). The lowest wind speed (3.20m/s) was recorded in December when the total volatile organic compound is high (305.59µg/m^3). The highest total volatile organic compound was recorded in the months of November, 2010 - March, 2011 while the lowest value was in July. This is because during the wet seasons, apart from dilution of the atmosphere, there is a wash down of Atmospheric Air by rainfall. By comparing the five industrial areas of Lagos state, Ikeja has the highest total VOC concentrations of 5669.85µg/m^3 while Isolo has the lowest value of 3899.16µg/m^3 (Ojiodu, 2012, Ojiodu *et al*, 2013). This may be due to more industries and more vehicular traffic because of people's patronage of such industries (Chang *et al*, 2005; Ohura *et al*, 2006; Hsieh and Tsai, 2003). It is evident that in addition to traffic emissions, industrial activities enhance the concentration levels of VOCs in the industrial areas. The comparison of VOCs in Nigerian industrial areas (Apapa, Iganmu, Ikeja, Ilupeju and Isolo) with other industrial areas of the world shows that the concentration of VOCs in the studied industrial areas is higher than those measured in Yakohama (Japan) (Vasu *et al.*, 2009); Tarragona (Spain) (Maria *et al.*, 2009); Edmonton (Spain) (Maria *et al*, 2009) and Gumi (Korea) (Al-Awadhi *et al.*, 2005). This may be due to lack of environmental monitoring and sanctioning by the body charged with such responsibility (FME, LASME). There is a significant difference (P< 0.05) between the dry and wet seasons in the levels of VOCs pollution in study areas in both seasons.

Conclusion

The spatial and temporal distribution of VOCs concentration in Isolo Industrial areas was found to be based on the industrial activities such as industrial solvent usage, petrochemical processes, storage and distribution of chemicals, combustion processes, vehicular/petroleum product emission and meteorological factors such as wind speed, direction of wind, humidity, rainfall and temperature.

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References

Agency for Toxic Substances and Disease Registry (ATSDR) (2001), Interaction profile of Benzene, Ethylbenzene, Toluene and Xylenes (BTEX) (draft for public comments) Atlanta: *Agency for toxic Substances and diseases Registry*, US Dept. of health and human services.

American Society for Testing and Materials (ASTM), Method D3686-84, (1988), Standard practice for sampling atmospheres to collect organic compound vapours, *Annual Book of ASTM Standard,* 3(11): 234 – 240.

Borton, A., Locoge, N., Veillerot, M., Galloo, J. C. and Guillermo, R. (2002). Characterisation of NMHCs in a French urban atmosphere: overview of the main sources. *Science Total Environment*, 292: 177-191.

Eljarrat, E. and Barcelo, D. (2003). Priority lists for Persistent Organic Pollutants and emerging contaminants based on their relative toxic potency in environmental samples. *Trends in Analytical Chemistry*., 22: 655-665.

Huang, H.O., Haghighat, F. and Blondeau, P. (2005), VOC adsorption materials. Influence of gas-phase concentration relative to humidity and VOC type: *Indicator Air*, 16(3): 236-247.

Kerbachi, R., Boughedaoui, M., Bounoue, L. and Keddam, M. (2006), Ambient air pollution by aromatic hydrocarbons in Algiers. *Atmospheric Environment*, 40: 3995- 4003.

Kim, Y. M., Harrad, S. and Harrison, R. M. (2001), Concentrations and sources of VOCs in urban and public microenvironments. *Environment Science Technology*, 35: 997 - 1004.

Lagos State Government (LASG) (2006). Lagos State Regional plan (1980-2000). Ministry of Economic planning and Land Matters, *Urban Regional plan Division*, Ikeja, Lagos.

Molina, L.T, Kolb, C.E., de Foy, B., Lamb, B.K., Brune, W.H., Jimenez, J.L., Ramos-Villegas, R., Saarmiento, J., Paramo-Figueroa, V. H., Cardenas, B., Gutierrez-Avedoy, V and Molina, M.J. (2007), Volatile Organic Compounds in Urban and industrial atmospheres: Measurement techniques and data analysis. *International Journal of Environmental Analytical Chemistry*, 83: 199 - 217.

Na, K., Kimb, Y.P. and Moon, K.C. (2003). Diurnal characteristics of Volatile Organic Compounds in the Seoul atmosphere. *Atmospheric Environment*, 37: 733–742.

National Population Commission NPC, (2009). Misunderstanding, Misperception and Misrepresentation of Census 2006. A rejoinder to the Publication; *The Falsification of Lagos Census Figures by Lagos state*.

NIOSH publication No. 88-111 [Online], http/www.oshasic.gov./SLT/health/guildelines (accessed Nov. 22, 2007).

Ohura, T., Amaigai, T. and Fusaya, M. (2006). Regional assessment of ambient Volatile Organic Compounds in an industrial harbour area. Shizuoka, Japan. *Atmospheric Environment,* 40: 238-248.

Ojiodu, C.C. (2013). Temporal and spatial variation of Ambient Volatile Organic Compounds (VOCs) Pollution in Ikeja Industrial Areas of Lagos State, Southwestern-Nigeria. *International Journal of Research in Chemistry and Environment,* 3(2): 12–23.

Ojiodu, C.C., Okuo, J.M. and Olumayede, E.G. (2013). Spatial and temporal variability of volatile organic compounds (VOCs) pollution in Apapa industrial areas of Lagos State, Southwestern-Nigeria. *Academia Journal of Environmental Sciences,*1(3): 053- 061.

Okuo, J.M., Ogbeifun, D.E, Oviawe, A.P. and Nwosu, E.C. (2011). Air quality Status of Volatile Organic Compounds in Health and Financial Institution Microenvironments in Benin City, Nigeria. *Global Journal of Pure and Applied Sciences*, 17(3): 299-306.

Okuo, J. M., Ojiodu, C.C. and Olumayede, E.G. (2012a), Volatile Organic Compounds (VOCs) Monitoring in Two Contrastive Industrial Areas of Lagos, Nigeria. *Nigerian Journal of Applied Sciences*, 30: 87-100.

Okuo, J.M., Ojiodu, C.C. and Olumayede, E.G. (2012b). Ambient Air Pollution by Volatile Organic Compounds (VOCs) in Ikeja Industrial Area of Lagos State, Southwestern-Nigeria. *Nigerian Journal of Applied Sciences*, 30: 138 - 149.

Olumayede, E.G., Okuo, J.M. and Ojiodu, C.C. (2011), Weekdays-Weekends Variations of Total volatile organic compounds in the atmosphere of Benin City, Southern–Nigeria. *International Journal of Chemical Sciences*, 4(2): 405-415.

Schlink, U., Rehwagen, M., Damm, M., Riccter, M., Borte, M. and Herbarth, O. (2004). Seasonal cycle of indoor-VOCs: comparison of apartments and cities. *Atmospheric Environment,* 38: 1181-1190.

Silke, M., Abou, B. R. and Uwe, S. (2010), Spatial and Temporal Variation of outdoor and indoor exposure of VOCs in Greater Cairo. *Atmospheric Pollution Research*, 1: 94 – 101.

Simona, N., Loris, T., Pietro, T., Jonathan, W., Geraint, E. and Ovidiu, P. (2009). Determining the levels of Volatile Organic Compounds in urban Air using a Gas Chromatography-Mass Spectrometry method. 1-4. *Journal of Environmental Health.*

So, K.L. and Wang, T. (2004). C_3 - C_{13} non-methane hydrocarbons in Subtropical Hong-Kong, Spatial-temporal variation, Sources-receptor relationships and photochemical reactivity, *Science of Total Environment*, 328: 161–174.

Son, B., Breysse, P. and Yang, W. (2003). Volatile Organic Compounds in residential indoor and outdoor and its personal exposure in Korea. *Environment Intern.*, 29: 79–85.

Statistical Package for Social Sciences (SPSS) Inc., (2007). SPSS for Windows, Version 15, *SPSS Inc. Chicago, Ilinois.*

Ulman, M. and Chilmonczy, Z. (2007), Volatile Organic Compounds - Components, Sources, Determination. *A review. chemia Analityczna.,* 52: 173 - 200.

Wang, S., Ang, N.H.M. and Tade, M.O. (2007). Volatile Organic Compounds indoor Environment and Photo Catalytic. Oxidation. 694 - 702.

Zhang, Y.X., Tao, S., Cao, J. and Raymond, M. C.J. (2007). Emission of polycyclic aromatic hydrocarbons in China by county. *Environmental Science and Technology*, 41: 683 – 689.