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Spatial and temporal variability of volatile organic compounds (VOCs) pollution in Apapa industrial areas of Lagos state, southwestern-Nigeria

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ABSTRACT

The results of temporal and spatial distribution of volatile organic compounds in ambient air in Apapa Industrial Area during May, 2010 to April, 2011 are presented. This 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. The VOCs were classified thus: aromatics 43%, halogenated 28%, esters 4%, ketones 13%, alcohols 6 %, ethers 6%. There is a significant difference (P_{value} < 0.05) between the levels of VOCs in Apapa. Despite a Comparatively higher concentrations of VOCs at the studied sites, there is a significant difference in the spatial distribution. At a 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 - ways factor ANOVA analysis of the monthly average of total volatile organic compounds revealed that there is significant difference (P_{value} < 0.05) in temporal and spatial 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 Apapa are mainly Anthropogenic and three (3) factors were identified as sources of VOCs in the studied area with Industrial and emissions from traffic dominating.

Key words: Ambient, Spatial, Industrial, Anthropogenic, Temporal.

INTRODUCTION

Lagos State one of the megacities of the world is facing serious air quality problems as a result of increase in Urbanization and Industrialization [1]. There has been a continuous increase in levels of pollutants (VOCs) and environmental emanating from these pollutants particularly fron the second half of the last century [2]. Apapa industrial area is situated in Apapa Local Government area in Lagos division of the five divisions of Lagos state. It is located on longitude 6.26^0 N and latitude 3.21 – 3.21^o E. It's population within the Local Government area was estimated at 517,362 people according to the 2006 final census results [3]. Conspicuous in these area are various industries such as cement, sugar, pharmaceutical, plastic, paint, cosmetic, soap and detergent, heavy chemical industries etc. Apart

from this, we have clusters of filling stations, official and residential houses, Gas plants, Motor parks, shopping moore and eatries. The land - use pattern of Apapa industrial area is mostly industrial and partly residential. Apapa is a host community to two major Nigerian Sea ports, Apapa and the Tin can Island ports [4]. 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 [5,6] . Studies have shown that VOCs enter the human bloodstream through the following means inhalation , ingestion and through the skin [7]. The short term adverse effects include conjunctive irritation, nose and throat discomfort, headache and sleeplessness, allergic skin reaction, nausea, fatique and dizziness. While the Long term adverse effects include loss of coordination, leukamia, anaemia, cancer and damage to liver, kidney and central nervous system [8,9,10]. Vehicular emissions apart from Industrial emissions form 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 [11]. Several researchers have attempted VOCs monitoring studies over different parts of the world considering VOCs increasing importance in environmental issues [12,13,14]. Higher concentrations of VOCs were recorded in the morning and evening with low concentrations in the afternoon in central Seoul [15]. Weekdays - Weekends variations of total volatile organic compounds (TVOCs) in Atmosphere of Benin City, Southern, Nigeria was determined by [16]. Except for the difference caused by the variation of temperature, the spatial distribution of emission density remained the same among different seasons [17]. Meterological conditions and photochemical activities cause diurnal, seasonal and annual variations of VOCs concentrations [18,19,20]. The seasonal variation of measured concentrations of VOCs in certain periods (e.g summer months) have to be adjusted for other periods using appropriate cycle factors [21]. 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 [22]. The objective of this present study is to investigate the spatial and temporal variations of VOCs pollution and the possible effects of and meterological conditions in the studied area.

MATERIALS AND METHODS

Sampling Locations

This study was conducted in Apapa Industrial of Lagos state. Apapa 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 studied area. 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.

Sampling Device and Collection of Ambient VOCs

Ambient air samples were collected using ORSA 5 diffusion tubes from Dragger Safety, Lubeck, Germany. The Sampler comprises a glass sampling tube open at both ends and filled with activated charcoal. Each opening in sampling tube is filled with cellulose acetate diffusion barrier. Ambient air diffuses into the sampling tube in a controlled manner. The cross section, tube length and diffusion coefficient are constant and expresses the sampling rate [23].

Table 1: Monitoring Locations, their Characteristics and Co - ordinates at Apapa Industrial Area.

Site	Code	Co-ordinates	Site description
1.	APOB	N 6^0 26' 06.1" E 3^0 21' 49.0"	Creek road. Created at Oxford Biscuit. A location with high vehicular activities.
2.	APUT	N 6^0 26' 03.9" E 3^0 21' 58.9"	UTC . A site located at the United Trading Company,PLC with high commercial activities.
3.	APNG	N 6^0 26' 7.9" E 3^0 22' 8.9"	Nidogas . A site located along creek road.A location with high traffic density.
4.	APWH	N 6^0 26' 19.2" E 3^0 22' 17.6"	Warehouse . Created at Burma road. A location with artisan shops.
5.	APFG	N 6^0 26' 24.4" E 3^0 22' 26.4"	Foorma Guest site. Apart from traffic density. It is a location with residential buildings and commercial shops.
6.	APUB	N 6^0 26' 32.7" E 3^0 22' 34.5"	Burma road.A site created at Union Bank Registrars.
7.	APCR	N 6^0 26' 37.8" E 3^0 22' 24.2"	This site is located at Commercial road junction. A location with high traffic density.
8.	APAR	N 6^0 26' 10.9" E 3^0 21' 53.5"	Apapa site is created along Apapa road by Total filling station.A site with high human activities such as hawking of cloths, footwears, food and plastic items e.t.c
9.	APCC	N 6^0 26' 21.6" E 3^0 22' 06.5"	This site is at Crowther crescent by Apapa club.
10.	APOC	N 6^0 26' 16.5" E 3^0 21' 49.7"	Calcutta site created along Ogedengbe road. A site with high human activities such as hawking of various household items such as cloths, footwears, perfumes e.t.c.

Sampling Routine

Sampling were carried out during dry and wet seasons. The samplers were exposed at a height of 1.5 - 2.0 metres. Sampling was done 4 times a month, for a period of 12 months. The samplers were harvested after seven days and taken to the laboratory for analysis. A total of 480 samples were collected for the two seasons. During each round of ambient sampling, meterological parameters such as temperature, wind speed, wind direction and rainfall were also recorded.

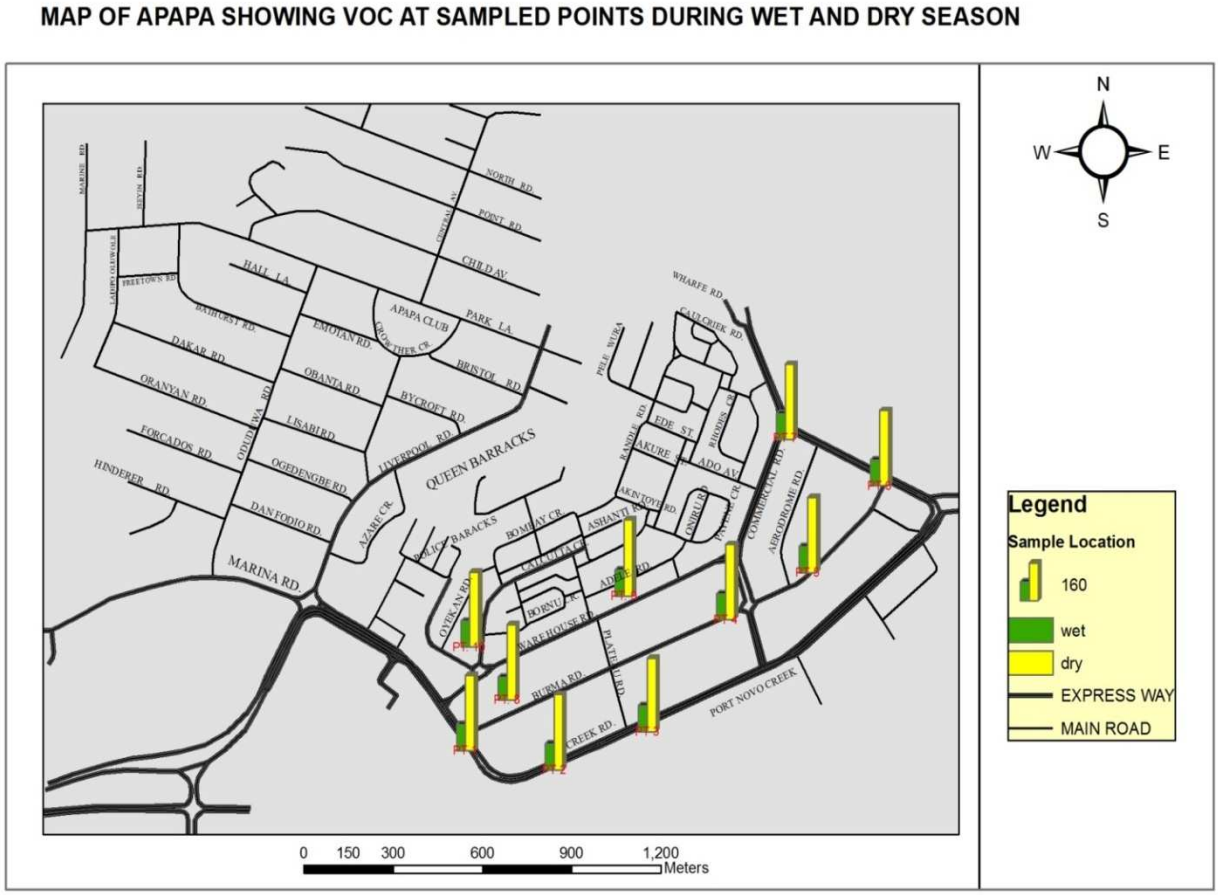

Fig 1: Showing the total Volatile Organic Compounds during Wet and Dry seasons.

Table 2: Monthly Measured Mean Concentration of VOCs at Apapa 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	15.66 ± 0.01	15.68 ± 0.01	15.65 ± 0.02	15.18 ± 0.13	6.72±0.06	6.66±0.06	6.54±0.06	6.57±0.06	6.58±0.06	6.61±0.06	11.78 ± 0.02	11.77 ± 0.02
EthylBenzene	10.39 ± 0.02	10.39 ± 0.01	10.38 ± 0.01	10.02 ± 0.20	4.26±0.03	4.24±0.02	4.17±0.02	4.20±0.02	4.22±0.02	4.22±0.02	10.34 ± 0.02	10.40 ± 0.02
IsopropylBenzene	9.73 ± 0.01	9.83 ± 0.09	9.63 ± 0.04	9.18 ± 0.18	2.20±0.03	2.18±0.03	2.11±0.03	2.12±0.03	2.13±0.03	2.14±0.03	9.67 ± 0.02	9.72 ± 0.03
Napthalene	11.42 ± 0.03	11.40 ± 0.01	11.29 ± 0.07	40.40 ± 58.85	3.50±0.03	3.45±0.02	3.40±0.02	3.41±0.02	3.42±0.02	3.43±0.02	11.33 ± 0.02	11.43 ± 0.02
n-ButylBenzene	9.34 ± 0.01	9.34 ± 0.03	9.28 ± 0.05	8.87 ± 0.16	3.09±0.03	3.07±0.03	3.01±0.02	3.04±0.02	3.05±0.02	3.06±0.02	9.29 ± 0.03	9.35 ± 0.02
n-PropylBenzene	10.69 ± 0.03	10.72 ± 0.01	10.61 ± 0.05	10.22 ± 0.17	3.26±0.04	3.21±0.03	3.17±0.03	3.21±0.03	3.22±0.03	3.27±0.03	10.66 ± 0.01	10.66 ± 0.02
Toluene	13.42 ± 0.02	13.43 ± 0.02	13.42 ± 0.01	13.50 ± 1.06	6.40±0.05	6.36±0.05	6.23±0.05	6.25±0.05	6.28±0.05	6.30±0.05	13.35 ± 0.03	13.41 ± 0.02
m+p-Xylene	39.72 ± 0.04	39.68 ± 0.01	39.64 ± 0.02	38.58 ± 1.41	13.67±0.13	13.48±0.12	13.27±0.10	13.32±0.11	13.35±0.11	13.38±0.11	39.71 ± 0.02	39.72 ± 0.02
o-Xylene	10.56 ± 0.01	10.59 ± 0.02	10.57 ± 0.02	10.09 ± 0.17	5.68±0.04	5.66±0.04	5.60±0.04	5.61±0.04	5.62±0.04	5.63±0.04	10.48 ± 0.01	10.56 ± 0.02
HALOGENATED VOCs												
BROMIDES												
Bromomethane	10.40 ± 0.01	10.40 ± 0.01	10.37 ± 0.02	10.00 ± 0.19	3.80±0.04	3.33±0.04	3.20±0.04	3.25±0.04	3.29±0.04	3.30±0.04	10.34 ± 0.01	10.39 ± 0.02
Bromoform	8.71 ± 0.02	8.72 ± 0.02	8.69 ± 0.03	8.24 ± 0.17	2.20±0.03	2.18±0.03	2.11±0.03	2.14±0.03	2.15±0.03	2.17±0.03	8.71 ± 0.02	8.73 ± 0.00
CHLORIDES												
ChloroBenzene	15.26 ± 0.02	15.25 ± 0.02	15.26 ± 0.03	14.90 ± 0.14	7.12±0.26	7.09±0.26	7.00±0.26	7.05±0.26	7.06±0.26	7.10±0.26	15.20 ± 0.02	15.25 ± 0.02
Chloroform	12.38 ± 0.01	12.39 ± 0.01	12.35 ± 0.03	11.96 ± 0.19	6.07±0.04	6.06±0.04	5.94±0.04	5.96±0.04	5.97±0.04	5.99±0.04	12.35 ± 0.01	12.38 ± 0.02
Carbontetrachloride	14.07 ± 0.03	14.09 ± 0.03	14.08 ± 0.03	13.44 ± 0.34	5.30±0.03	5.28±0.03	5.21±0.03	5.22±0.03	5.25±0.03	5.27±0.03	14.05 ± 0.01	14.08 ± 0.02
Methylchloride	10.29 ± 0.01	10.32 ± 0.02	10.30 ± 0.01	9.88 ± 0.18	3.85±0.03	3.80±0.03	3.77±0.03	3.81±0.03	3.84±0.03	3.86±0.03	10.25 ± 0.02	10.30 ± 0.01
Trichloroethane	11.47 ± 0.07	11.27 ± 0.01	11.27 ± 0.05	11.03 ± 0.15	3.00±0.02	2.96±0.02	2.91±0.02	2.93±0.02	2.94±0.03	2.97±0.02	11.45 ± 0.01	11.49 ± 0.02
Trichlorofloromethane	12.39 ± 0.05	12.45 ± 0.03	12.35 ± 0.08	12.17 ± 0.32	3.22±0.03	3.16±0.02	3.10±0.02	3.15±0.02	3.17±0.02	3.20±0.02	12.34 ± 0.01	12.38 ± 0.03
1,2-Dichloropropane	11.23 ± 0.01	11.24 ± 0.02	11.22 ± 0.02	10.86 ± 0.17	2.40±0.03	2.10±0.02	2.02±0.02	2.04±0.02	2.08±0.02	2.09±0.02	11.20 ± 0.01	11.23 ± 0.01
2,2-Dichloropropane	10.40 ± 0.02	10.42 ± 0.01	10.40 ± 0.02	10.10 ± 0.14	3.41±0.05	3.36±0.05	2.29±0.05	2.32±0.05	3.26±0.05	3.31±0.05	10.38 ± 0.01	10.42 ± 0.02
Tetrachloroethane	14.33 ± 0.02	14.33 ± 0.03	14.31 ± 0.03	13.97 ± 0.12	3.49±0.04	3.45±0.04	3.36±0.04	3.40±0.04	3.41±0.04	3.45±0.04	14.27 ± 0.02	14.34 ± 0.01
KETONE VOCs												
Acetone	13.73 ± 0.02	13.73 ± 0.01	13.63 ± 0.08	13.21 ± 0.18	6.75±0.04	6.68±0.04	6.60±0.04	6.63±0.04	6.64±0.04	6.69±0.04	13.69 ± 0.03	13.74 ± 0.01
4-Methyl-2-Pentanone	9.32 ± 0.01	9.33 ± 0.02	9.32 ± 0.02	8.86 ± 0.32	1.45±0.05	1.42±0.05	1.29±0.05	1.32±0.05	1.33±0.05	1.38±0.05	9.27 ± 0.02	9.33 ± 0.02
ESTER VOC												
Isopropylacetate	7.51 ± 0.02	7.50 ± 0.03	7.46 ± 0.02	7.09 ± 0.11	2.91±0.02	2.84±0.02	2.83±0.02	2.86±0.02	2.87±0.02	2.88±0.02	7.48 ± 0.02	7.52 ± 0.02
ALCOHOL VOC												
Ethanol	16.46 ± 0.02	16.46 ± 0.02	16.42 ± 0.03	16.13 ± 0.16	6.10±0.02	6.08±0.02	6.00±0.02	6.01±0.02	6.04±0.02	6.05±0.02	16.43 ± 0.02	16.49 ± 0.02
ETHER VOC												
Tetrahydrofuran	10.33 ± 0.02	10.34 ± 0.02	10.31 ± 0.02	9.92 ± 0.16	3.68±0.02	3.64±0.02	3.60±0.02	3.61±0.02	3.65±0.02	3.66±0.02	10.29 ± 0.03	10.34 ± 0.03

Analytical Methods

Extraction Process

After sampling, adsorption tubes were labeled and closed with special caps to avoid contamination and desorption. The samples were placed into tightly closed special plastic bags and kept in a freezer until they were processed. Before analysis, contents of both sections of the adsorbed tubes were placed into two different vials in which they were weighed, 10ml carbondisulphide (CS_2) was added as the extraction solvent to each tube [24]. Samples were extracted using a magnetic stirrer (Jenweary 1103) for 30min. The extracted samples were then filtered and stored in a freezer until they were analyzed using Gas Chromatographic instrument (GC) fitted with flame ionization detector (FID). The concentrations of the analyte were read from the calibration graph, which was done with standard solution.

Chromatographic Analysis

The extracted solutions were analyzed with gas chromatograph (GC) (Perkin Elmer Clarus 500) equipped with a flame ionization detector (FID). The GC / FID was standardized and calibrated by injecting about 2µL VOC - mix into it. The GC with a capillary column (Elite - V) (40m x 0.18mm x i.d 1.0µm) was used with an initial oven temperature of 35^0C (held for 2min) increased to 60^0C at a rate of 4^0C min^{-1} (held for 0min) and finally to 225^0C at the rate of 40^0C min^{-1}(held for 5min). Helium was used as carrier gas at a constant flow rate of 45ml min^{-1}. The bake time was 8 min at 260^0C. The split ratio is 1: 40 and the injection and detection temperatures were maintained at 250^0C and 280^0C respectively.

Table 3: Measured Mean Concentration of VOCs at Apapa Industrial Area During Dry and Wet Seasons (µg/m^3) n = 10

	MEAN	STD	MIN	MAX.		MEAN	STD	MIN	MAX
AROMATIC VOCs		**DRY**	**SEASON**				**WET**	**SEASON**	
Benzene	15.66	0.235	15.23	15.98		8.37	3.75	6.49	15.49
EthylBenzene	10.37	0.11	10.28	10.63		5.74	2.83	4.17	10.32
IsopropylBenzene	9.817	0.32	9.63	10.71		3.93	3.55	2.11	10.71
Napthalene	11.40	0.11	11.22	11.71		5.21	2.83	3.41	11.37
n-ButylBenzene	9.32	0.12	9.17	9.57		4.28	2.62	3.02	9.26
n-PropylBenzene	10.91	0.60	10.48	12.54		5.64	3.92	3.17	12.54
Toluene	13.40	0.09	13.26	13.52		8.67	3.56	6.23	13.52
m+p – Xylene	39.71	0.12	39.45	39.83		22.15	13.19	13.27	39.79
o-Xylene	10.53	0.15	10.32	10.72		5.61	0.05	5.54	5.70
HALOGENATED VOCs									
BROMIDES									
Bromomethane	10.38	0.09	10.19	10.48		3.29	0.04	3.21	3.33
Bromoform	8.71	0.05	8.61	8.79		2.17	0.03	2.11	2.21
ChloroBenzene	15.09	15.11	15.01	15.13		7.09	0.03	7.00	7.12
Chloroform	12.39	12.24	12.33	12.48		6.00	0.05	5.94	6.07
Carbontetrachloride	44.10	14.07	14.01	14.12		5.26	0.03	5.21	5.31
Methylenechloride	10.13	10.22	10.38	10.35		3.83	0.03	3.77	3.86
Trichloroethane	11.42	11.64	11.49	11.59		2.94	0.02	2.90	3.00
Trichlorofloromethane	12.27	12.19	12.22	12.14		3.17	0.03	3.11	3.22
1,2-dichloropropane	11.17	11.33	11.24	11.14		2.05	0.03	2.01	2.10
2,2- dichloropropane	10.26	10.48	10.49	10.43		3.04	0.50	2.29	3.41
Tetrachloroethane	14.28	14.18	14.27	14.22		3.42	0.04	3.36	3.49
KETONE VOCs									
Acetone	13.62	14.64	13.62	11.67		6.68	0.04	6.60	6.75
4-Methyl-2-Pentanone	9.27	9.30	9.24	9.22		1.38	0.05	1.29	1.45
ESTER VOC									
Isopropylacetate	7.62	7.42	7.66	7.30		2.87	0.03	2.83	2.91
ALCOHOL VOC									
Ethanol	16.29	16.47	10.34	16.37		6.05	0.03	6.00	6.10
ETHER VOC									
Tetrahydrofuran	10.33	10.24	10.28	10.39		3.65	0.02	3.61	3.68

Chemical Standards and Instrumental Calibration

External calibration was carried out with a Volatile Organic Calibration Mix containing 40 VOCs in 2000mgL^{-1} in Methanol (Supelco, Bellefonte, U.S.A.). The calibration was performed by analyzing diluted standards. The standard solution was prepared by dilution in CS_2 / methanol for gas chromatography. Seven calibration levels of concentration range of 0.1 and 3.0 mg·L^{-1} (0.1, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0) with CS_2 was prepared from stock standard in a clean vial. They were freshly prepared at

the moment of calibration. The instrumental calibration was performed by analyzing 2µL of the diluted standards, in order to obtain the relative response value (µv).

Statistical Analysis

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)[25].

Factor Analysis

The data acquired at Apapa Industrial Area were used to conduct PCA and the statistical results[11]. Three factors were extracted. The first factor (F1) explained 43.68% of the total variance and the second factor (F2) accounted for 38.94% while the last factor (F3) was responsible for 8.74% of the variance. **F1:** This is highly loaded with trichloroethane, chlorofoam, naphthalene, 2,2-dichloropropane and n-propylbenzene. These compounds are used as solvents in plastics, paints / pigments, pharmaceutical industries and also from gasoline evaporative sources in the vicinity of the studied area [26] . Gasoline evaporation and industrial solvent usage could be the main contributor to factor 1. **F2:** A high loading of ethanol, 4- methyl- 2 - pentanone, benzene and tetrahydrofuran were found in F2. These chemicals are released from exhaust of vehicles and are use in textile and cosmetic industries and cement depot in the studied areas. Therefore, factor 2 is due to vehicular emission and industrial solvent usage. **F3:** This factor was highly loaded in methylenechloride. This chemical is used as solvent in the paper and paint industries in the area as well as in the dry cleaning shops and also from burning of wood and bush in the studied areas. Methylene chloride is an indicator of biomass burning . Hence, this factor may be attributed to emission from industrial solvent usage and biomass burning.

Table 4: TVOCS, WIND SPEED, RELATIVE HUMIDITY, TEMPERATURE AND RAINFALL

MONTH	APAPA	RELATIVE HUMIDITY (%)	WIND SPEED ms^{-1}	RAINFALL (mm)	WIND DIRECTION
May-10	113.53	86	6.00	159.30	S
Jun-10	111.74	87	4.50	367.70	S
Jul-10	108.73	89	4.50	130.80	SW
Aug-10	109.43	88	5.70	190.60	SW
Sep-10	110.82	90	4.20	253.70	SW
Oct-10	111.41	84	3.70	122.80	SW
Nov-10	314.31	81	3.50	126.70	SW
Dec-10	314.98	77	3.20	76.70	S
Jan-11	319.21	61	3.30	38.00	SW
Feb-11	319.30	72	5.20	52.50	SW
Mar-11	318.21	77	4.60	69.00	S
Apr-11	337.80	79	5.50	136.20	S

SOURCE: NIGERIAN METEROLOGICAL AGENCY, 2010/2011

RESULTS AND DISCUSSION

Twenty- Six (26) VOCs were captured in each of the ten sites in Apapa industrial areas during the wet and dry seasons (Table 1) [27]. 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 2 to 8 times higher than the wet season(Table 3). The dry/wet ratio of the measured TVOC shows high level of VOCs in the dry seasons(Fig 1). The high ratio obtained is an indicated 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, footwares, cosmetics e.t.c . Similarly, high levels of VOCs were recorded with high temperature(Table 5).These high levels of VOCs were attributed to evaporation, dispersion and more photochemical reactions occurring during the season. 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 is 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, non - industrial and background areas reveal significant seasonal variability ($P_{value} < 0.05$) with high values obtained during the dry seasons (December) and low in the wet seasons (July). The effect of temperature and other climatological factors such as relative humidity, windspeed and direction were suggested as to playing more significant roles in causing seasonal variation[28,29]. 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 4) . The lowest windspeed ($3.20ms^{-1}$) was recorded in December. The highest total volatile organic compound was recorded in the month of April ($337.80\mu g/m^3$) while the lowest value was in July ($108.37\mu g/m^3$). This is because during the wet seasons, apart from dilution of the atmosphere, there is a washdown of Atmospheric Air[30]. There is a significant difference ($P_{value} < 0.05$) between the dry and wet seasons in the levels of VOCs pollution in studied areas in both seasons. Eight **(8)** out of the twenty - six (26) VOCs such as Chloroform, 1,2 - dichloropropane, isoprophylBenzene, toulene ,naphthalene , acetone, Benzene and trichlorofloromethane are the major ambient pollutants in Apapa industrial areas during the Dry and wet seasons, constitute ninety six percent (96%) of the pollution in the area (eigen value > 1) (Table 5)[27]. VOCS concentrations at Commercial Road Apapa constitutes Ninety six percent of the pollution in the entire Apapa locations during the Wet season while in Dry season, Burma Road constitutes Ninety six percent of the pollution in the entire Apapa locations during the Dry season. There is a significant difference in each of the sites during the wet and dry seasons ($P_{value} < 0.05$). The identified spatial and temporal significant variation observed in the studied Apapa Industrial sites could be attributed to difference in traffic density, variety of industrial activities, big factories and small businesses and from landfill and other waste processing activities from the natural environment.

Table 5: Total Variation (eigen value) of Pollutants

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.977	20.737	20.737	4.977	20.737	20.737
2	4.335	18.062	38.799	4.335	18.062	38.799
3	4.127	17.195	55.994	4.127	17.195	55.994
4	2.570	10.707	66.701	2.570	10.707	66.701
5	2.389	9.955	76.656	2.389	9.955	76.656
6	1.944	8.099	84.754	1.944	8.099	84.754
7	1.739	7.246	92.000	1.739	7.246	92.000
8	1.046	4.358	96.358	1.046	4.358	96.358

Extraction Method: Principal Component Analysis.

CONCLUSION

The spatial and temporal distribution of VOCs concentration in 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 meterological factors such as wind speed, direction of wind, humidity, rainfall and temperature.

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