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Spatial and Seasonal Variation of Volatile Organic Compounds (VOCs) in Ambient Air of an Open Dumpsite, Benin City, Southern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Authors JMO and AI designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Volatile organic compounds in municipal solid waste dumpsites are considered as one of the major issues in recent years. Open burning is also very common, which emits volatile organic compounds and pose a serious threat to the associated environment. Air samples were collected by passive sampler (ORSA 5). The air samplers were mounted at a height of 1.5 – 2.0 m and sampling were carried out four times a month for a period of 12 months. The adsorbed VOCs were desorbed with carbon disulfide (CS_2), and the solution analyzed using a Gas Chromatography (GC) instrument fitted with a flame ionization detector (FID). The results from the analysis of the air samples showed that twenty-six (26) VOCs were identified and quantified in the open dumpsite during the dry and wet seasons. The VOCs in the open dumpsite during the dry season were classified as follows: Alcohol 9%, aromatic 45%, halogenated compound 38%, ester, and terpinene 4% each. The levels of VOCs obtained in the studied areas in the dry season are 2 to 3 times higher than in the wet season. This may be attributed to metrological parameters and a greater number of anthropogenic

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activities such as storage and movement of waste, waste combustion, solvent discharge, vehicular exhaust, and petroleum product emissions. Principal component analysis revealed that the major sources of VOCs in the open dumpsite are mainly anthropogenic.

Keywords: VOCs; air pollution; dumpsite; seasonal variation.

1. INTRODUCTION

The presence of environmental pollution has been haunting the human world since early times and it is still growing due to a high rate of growth in developing countries. There is an imbalance between urban growth and the support infrastructure required to reduce the impact of urbanization. One of the consequences is the emergence of accelerated urban air pollution that has become a global concern. Municipal solid waste (MSW) normally called as ‘‘garbage’’ or ‘‘trash’’ is an inevitable byproduct of human activities. Population growth and economic development have lead to enormous amounts of solid waste generation by the dwellers in urban areas [1].

The population of Benin City the administrative headquarters of Edo State, Southern Nigeria rose from 780,976 to 1,085,676 in 2006 [2]. Therefore, a population projection growth rate of 2.78% is used to project the future population of the Benin metropolis. The implication of this increase in the population of the Benin metropolis means an increase in the generation of Solid Waste.

Urban MSW is usually generated in human settlements, small industries and commercial activities [3]. An additional source of waste that finds its way to the MSW stream is the waste from hospitals and clinics. In a majority of countries, most of the smaller geographic units do not have any specific techniques for managing these wastes. When these wastes are mixed with MSW, they pose a threat to health and also may have long-term effects on the environment [4]. Biological degradation of the waste is of great concern [5]. The level of VOCs emitted from open dumpsite has elicited concern due to implications for workers and neighboring residents [6].

There is little published data on VOCs levels in ambient air in or adjacent to open dump sites. Incidentally, very few of these data from open dump site have been reported in developing countries [7]. However, studies exist on the emission inventories. The short-long term adverse effects have been well documented [8]. Unfortunately, there has not been much systematic study of air pollutants in the Studied open dumpsites. In our preliminary study on the emission levels of ambient VOCs of the studied site, concentration up to TVOCs 47.36 ($\mu g/m^3$) were reported [7]. However, the data obtained was not adequate. In addition, the seasonal variation patterns have not been evaluated. Therefore, this study is the first of its kind in assessing the seasonal variation and to identifying the major sources of VOCs in the atmosphere of the Ikhueniro Dumpsite in Benin City.

2. MATERIALS AND METHOD

2.1 Study Area

Benin, the capital City of Edo State, is the fourth largest City in Nigeria. It has a geographic area of 434.98 km with a population of 3.6 million and a population density of 8,401 / km^2 which makes it Nigeria’s largest incorporated City. Benin City stretches East-West with a width of approximately 23.63 km and North-South with a width of approximately 31.11 km. The mean annual rainfall in Benin City is approximately 135.7 mm. March is the coldest month with a mean monthly temperature of 26°C. December is the hottest month with a mean monthly temperature of 30.4°C. The average annual temperature is 28.5°C [9].

2.2 Site Description

The study was carried out at a major dumpsite in Ikhueniro. Ikhueniro is located in the Uhunmwode Local Government Area of the state with Administrative headquarters at Ehor. The Ikhueniro dumpsite is the largest and the major open dumpsite in the Benin metropolis. The centre of the dumpsite lies at latitude 06°19’38.1’’N and longitude 05°44’5.2’’E. Uhunmwode has an area of approximately 2,03 3 / Km^2 and a population of about 121,749 with a population density of 59.89/Km^2 according to the 2006 census. The distance of sampling location from the city center is approximately 14 Km.

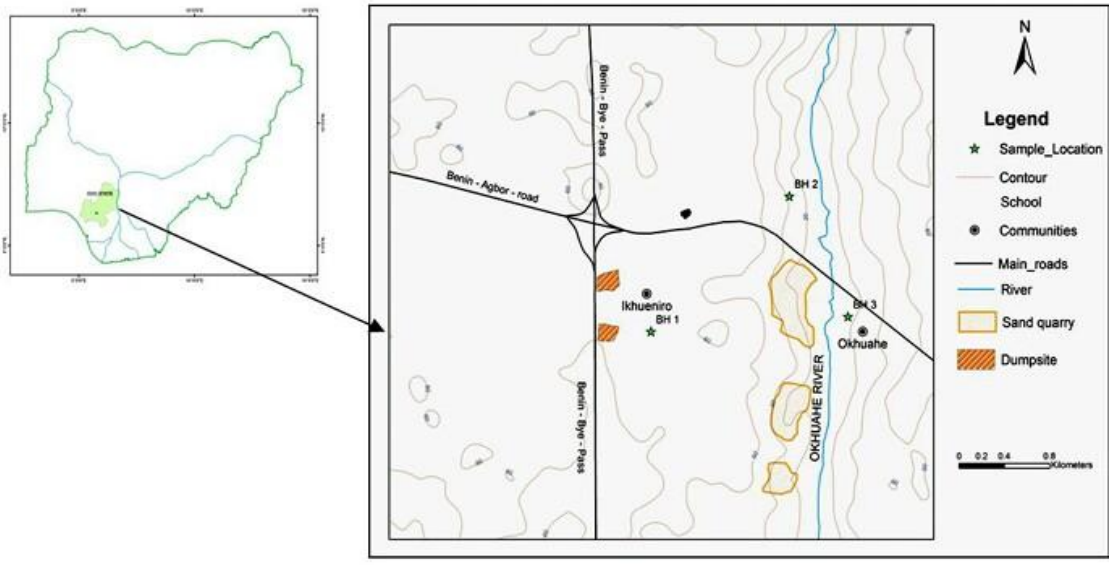

Fig. 1. Map of Edo State showing the Ikhueniro dumpsite and neighboring communities

2.3 Sampling Device and Collection of Ambient VOCs

Ambient air samples were collected using (ORSA 5 diffusion tubes) Drager safety, Lubeck Germany. The tube is cylindrical and approximately 2 cm in length and 0.2 mm in diameter. It is made of glass, opened at both ends and filled with activated charcoal. Each opening in the sampling tube is filled with a 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 express the sampling rate [10]. The diffusive passive sampler fulfilled many of the logistical requirements of an ideal ambient monitor [11]. A validation process for diffusive sampler has been performed [12,8].

2.5 Sampling Routine

Sampling was carried out during the dry and wet seasons. The sampler tubes were exposed by removing them from the transportation jar. The transportation jar was resealed and set aside so that it can later be used to resend the sampling tube to the laboratory. The tubes were then clamped to its holder and were suspended at a height of approximately 1.5-2.0 meters, which is within the human breathing zone. Care was taken to ensure that nothing was blocking the cellulose acetate opening of the sampling tube. The samplers were harvested after seven days and taken to the laboratory for analysis. A total of 45 samples were collected for the two seasons.

2.6 Extraction Process

After sampling, adsorption tubes were labeled and closed with special caps to avoid contamination and desorption. The samples were placed in a tightly closed special plastic bag and kept in a freezer until they were processed. Before analysis, contents of both sections of the adsorbed tubes were placed in a vial, 10 ml carbon disulfide (CS_2) was added as the extraction solvent to each tube. Samples were extracted using a magnetic stirrer (Jenweary, 1103) for 30 min [8,13]. The extracted samples were then filtered and stored in a freezer until they were analyzed using a Gas Chromatographic instrument (GC) fitted with a flame ionization detector (FID). The concentrations of the analyte were read from the calibration graph.

2.7 Meteorological Data

Meteorological data such as average monthly air temperature (°C), relative humidity (%), and wind speed ($m \cdot s^{-1}$) for the sampling period were measured simultaneously using a humidity/temperature meter, with resolutions of 0.1% RH and 0.1°C (model RS 1364, RS Components Ltd, UK). At the same time, wind speeds were measured using an LM-8000 anemometer with a resolution of 0.1 $m \cdot s^{-1}$ (Heatmiser UK Ltd.)

3. RESULTS AND DISCUSSION

3.1 Ambient Concentrations of Abundant VOCs

A total of twenty-six (26) VOCs species were successfully identified and quantified in the ambient air of Ikhueniro open dumpsite. The volatile organic compounds (VOCs) in the open dumpsite during the dry season were classified as follows: alcohol 9%, aromatic 45%, halogenated 38%, ester, and terpinene 4% each (Fig. 2). Ethanol and benzene have the highest values of 45.89 and 42.30 μg/m^3 respectively of all the VOCs captured during the sampling period. The fourth week of sampling had a high mean concentration of 21.59 ±2.34 μg/m^3 during the dry season (Fig. 3). Toluene had a maximum of 23.21 μg/m^3 in the fourteenth week. These values are an in agreement with other studies [14,15] The facility is poorly managed with a high level of combustion of petrochemical wastes that are dumped in an uncontrolled manner and traffic activities of heavy-duty vehicles.

Ethylbenzene was quantified in all samples all through the sampling period with the highest 39.45 μg/m^3 recorded in the fourth week. That week was characterized by high traffic density. Among the xylenes, o-xylene was the most prevalent in the ambient air. In the ninth week of sampling (m+p) - xylene, a diesel related component had a high concentration with a maximum of 14.87 and a mean value of 21.78±2.8 μg/m^3. This may be attributed to heavy truck within and outside the dumpsite perimeter fence.

The halogenated VOCs species were dominated by chlorobenzene, tetrachloroethane, and trichloroethylene. The highest concentration of these three species were 25.01, 32.01 and 29.34 μg/m^3, these values were quantified in week 6, 4 and 12 respectively (Table 1). The total concentration of VOCs (TVOCs) was obtained by summarising the concentration of individual species detected at each sampling site. Week twenty-three has the least TVOCs of 131.07 ±0.53 μg/m^3 (Fig. 3). Terpinenes and ester VOCs were observed in each of the samples with the maximum levels being obtained in the seventh week (α-pinene 7.03 μg/m^3, β-pinene 9.12 μg/m^3). Terpinenes are odour source in an open dumpsite [16]. The effect of biogenic emissions of terpinenes on urban air quality can be predicted. The study identified α- and β-pinene as being the dominant terpinenes emitted together with the lesser amount of camphene and limonene. In this study the proportions of the aforementioned compounds in ambient air are very similar, with α- and β-pinenes accounting for between 26% and 49% (<50%) of the total terpinenes concentrations quantified. This would suggest that the majority of the sources of terpinenes are direct emissions from household detergents and air fresheners. Other potential sources of terpenes are biogenic emissions due to the volatilization of compounds contained in plant biomass wastes, such as trees and leaves, shrubs and wasted rotted vegetables [16]. Ester VOCs ranges from 3.22 to 15.78 μg/m^3. The high concentration of ethanol and chloroform all through the sampling period is no doubt a reflection of the presence of textile waste, pigment and numerous spray cans of various compositions. Ethanol accounted for 17.98 μg/m^3 and had the highest individual VOC concentration. This may be due to the waste combustion and degradation processes. The waste degradation processes usually produce substantial levels of these compounds. Their levels in open dumpsites are dependent upon both the waste decomposition and the stage reached in the decomposition process [7]. The predominance of VOCs in open dumpsites is usually associated with older refuse together with a corresponding decrease in the levels of halogenated and oxygenated compounds such as alcohols [17].

In the wet season, a total of Twenty Six (26) VOCs were also identified and quantified in the ambient air of Ikhueniro open dumpsite. Among which were one (1) alcohol, ten (10) aromatic compounds, ten (10) halogenated compound two (2) ester, and three (3) terpinene compounds. Fig. 5 displays the TVOCs distribution by compound type in the sampling site. The figure clearly shows spatial variation in VOCs speciation during the twenty-two (22) week of measurement in the wet season. The most abundant class of VOCs species were aromatic VOCs accounting for 37% of the total volatile organic compounds (TVOCs), halogenated 21%, ester 32%, ethanol contributed 7%, and terpinene 3% (Fig. 4).

The mean concentration of halogenated VOCs in the dumpsite during the wet season ranges from 5.7 to 19.1 μg/m^3. The halogenated VOCs do not only emanate from the combustion of waste but

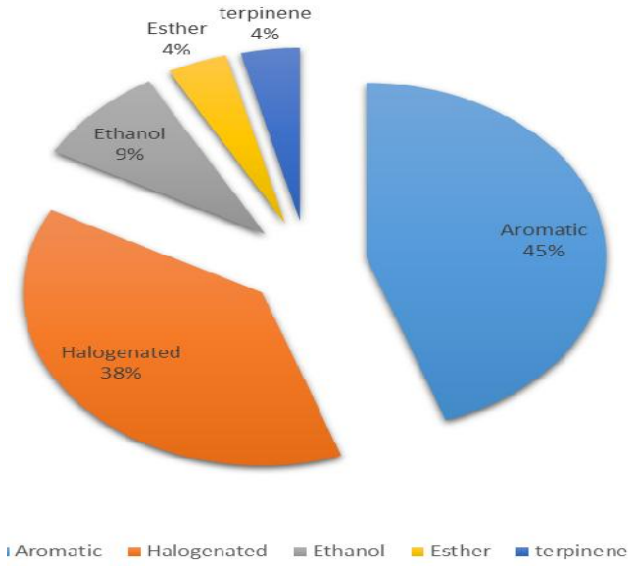

Fig. 2. Percentage composition of VOCs in the dry season

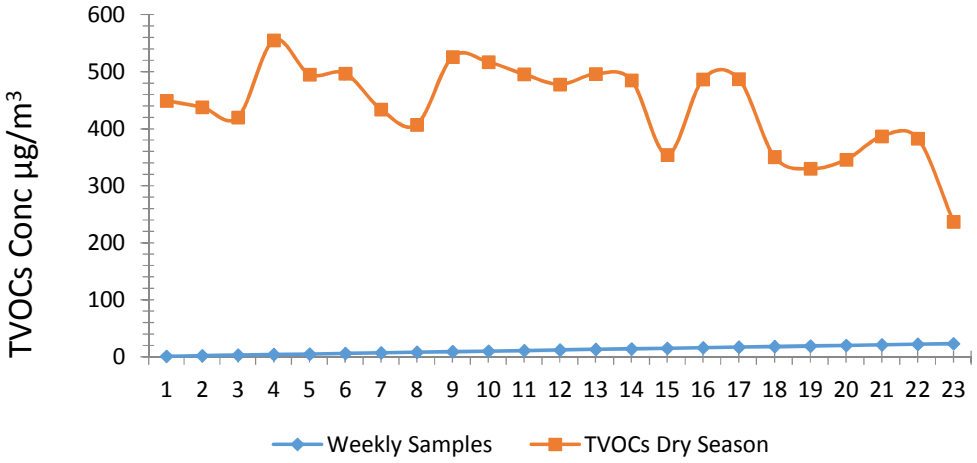

Fig. 3. Total VOCs concentration Per/ Week in the dry season

also from surrounding traffic along the dumpsite location. The concentration of terpinenes ranges from 2.06 to 11.34 µg/m^3, while for VOCs (tetrahydrofuran) the range is 6.78 to 1.24 µg/m^3. The tenth week has the highest concentration of ester VOCs in the studied dumpsite. This may be attributed to a substantial quantity of paint, textile and cosmetic waste that are dumped indiscriminately.

The main emission sources for VOCs in the dumpsites may be from plastics, paint solvents, oil, cleaning and degreasing agents, dry cleaning fluids, etc. A study report from the different disposal sites in the UK measured more than 140 VOCs. Among them, 90 VOCs were almost common in all the seven sites [18,19]. It was reported that this group of VOCs were produced predominantly from the direct volatilization of compounds contained in the waste, and are less likely to be produced from biological degradation process during wet seasons of the year.

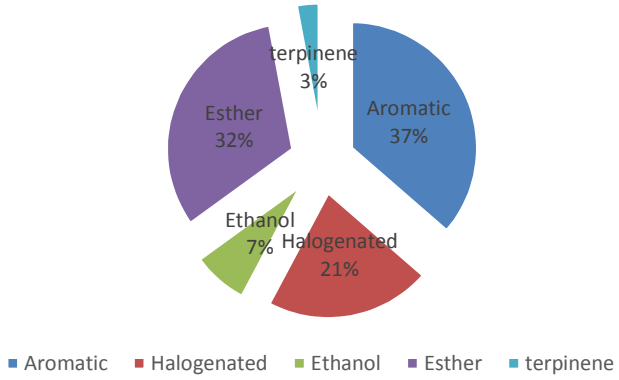

Fig. 4. Percentage composition of VOCs in the wet season

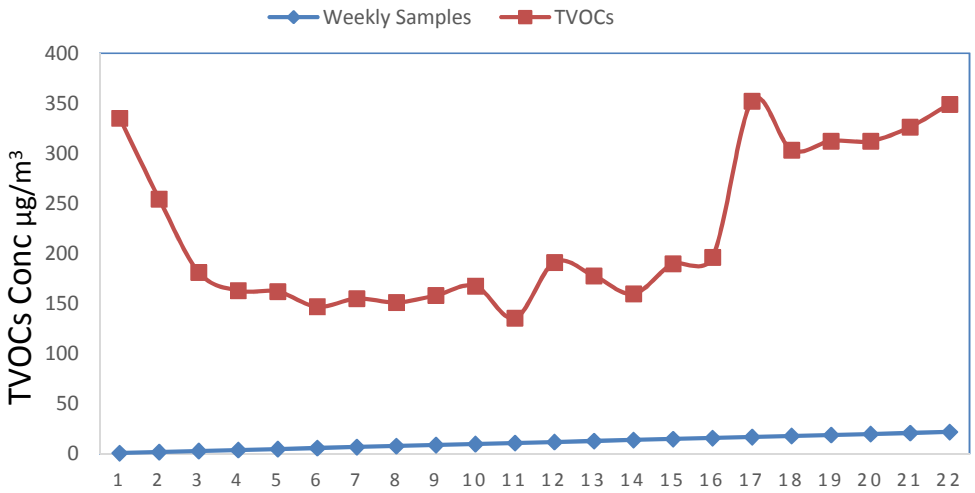

Fig. 5. Total VOC concentration Per/ Week in the wet season

3.3 Comparison of Ambient Concentrations of Abundant VOCs during Dry and Wet Season

Twenty-Six (26) VOCs were captured in each of the 45 weeks during the wet and dry seasons (Table 1). The levels of VOCs obtained in the studied areas in the dry season are 2 to 3 times higher than the wet season. This may be attributed to meteorological parameters (precipitation, temperature, wind speed, wind direction, humidity) and greater anthropogenic activities such as storage and movement of waste, waste combustion, solvent discharge, vehicular exhaust, and petroleum product emissions. This gives an indication of pollution strength and allows for the comparison of the variability of VOCs. Fig. 6 presents the monthly variations of TVOCs during the wet and dry seasons respectively. The measured TVOCs values were higher from October to March (399.19 to 517.21 µg/m^3) the highest concentration was obtained in December (551.43 µg/m^3) while the lowest was observed in July-August (104.4 to 149). The months with highest concentrations correspond to dry season and the lowest to wet season of the year. The temperature during the wet season ranges between 20 and 30°C. Dry season temperature ranges between 32 and 37°C. It is no doubt that the seasonal variation in temperature greatly influences the pollutant concentrations in the atmosphere of the studied area.

3.4 Statistical Analysis

Data obtained are expressed as mean ± standard deviation. Factor analysis was done using principal component analysis (PCA) techinique.

Table 1. Monthly measured mean concentrations of VOCs at the Ikhueniro open dumpsite in (µg/m^3)

	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Ethanol	17.42	0.94	21.42	0.87	29.22	5.54	20.93	9.03	15.85	2.50	16.21	2.37	17.71	1.24	21.01	4.27	21.01	4.27	39.87	4.71	31.24	1.76	23.90	6.93
Aromatic VOCs																								
Benzene	9.50	1.31	14.03	0.74	24.73	6.61	22.86	4.84	13.20	5.06	13.73	7.01	19.61	6.73	22.26	6.54	22.26	6.54	40.10	4.85	33.70	6.35	19.98	6.97
Ethylbenzene	8.42	1.27	9.15	4.89	18.24	6.94	14.68	6.60	5.29	3.11	12.23	7.80	9.27	2.02	9.88	7.65	9.88	7.65	28.44	7.38	31.66	2.72	18.89	8.22
Isopropyl benzene	7.09	1.42	11.90	0.61	16.03	2.50	17.46	10.22	8.15	2.49	8.58	2.47	13.95	11.45	16.16	6.02	16.16	6.02	20.06	2.59	18.98	1.37	13.58	4.35
Naphthalene	7.48	0.53	14.85	0.81	17.19	1.38	11.54	4.00	6.64	1.79	6.44	2.47	8.74	1.85	14.04	4.43	14.04	4.43	21.28	8.40	25.69	3.11	13.88	6.89
n-Butyl benzene	6.54	0.41	15.78	0.46	15.79	1.20	10.52	4.19	5.40	1.19	2.78	1.97	6.90	0.49	12.56	5.25	12.56	5.25	18.42	4.93	19.96	2.92	12.32	5.43
n-Propylbenzene	6.05	0.58	11.89	0.64	10.60	0.51	8.74	2.83	4.23	2.02	3.50	1.86	5.96	1.59	9.44	3.89	9.44	3.89	18.61	5.97	18.83	1.59	12.32	5.25
Toluene	5.87	0.84	11.46	0.67	12.04	0.92	8.27	2.34	5.78	1.31	4.23	2.12	6.28	0.31	10.36	3.78	10.36	3.78	18.28	3.00	17.10	2.22	10.59	5.05
m + p-Xylene	5.09	1.02	9.87	0.66	9.85	0.20	7.02	3.12	6.00	1.42	3.65	1.09	3.69	1.19	8.79	2.80	8.79	2.80	11.74	1.75	8.11	2.29	3.70	1.88
o-Xylene	4.72	0.64	11.27	0.20	10.90	0.68	8.54	3.01	4.12	0.82	3.27	1.42	4.50	0.90	9.29	4.36	9.29	4.36	14.55	3.13	12.43	1.76	7.80	1.71
Styrene	6.84	0.70	16.57	0.91	15.10	1.07	10.76	3.60	5.35	2.10	5.91	1.54	6.35	0.83	13.09	5.75	13.09	5.75	19.86	9.48	26.91	4.64	14.07	6.29
Halogenated VOCs																								
Chlorobenzene	7.88	0.51	16.60	0.75	15.76	0.89	11.46	3.62	8.04	1.34	6.05	1.95	9.41	3.07	13.08	5.16	13.08	5.16	24.47	0.45	23.20	2.12	15.07	5.77
Chloroform	3.08	0.88	9.90	0.49	9.26	0.32	5.27	2.62	4.90	1.41	5.07	2.13	3.15	1.83	8.57	1.77	8.57	1.77	11.37	1.49	9.15	2.42	4.33	1.90
Carbon tetrachloride	4.05	0.65	7.21	0.46	7.49	0.46	3.82	2.78	4.94	0.72	5.68	2.84	3.15	0.80	6.56	1.46	6.56	1.46	9.18	0.79	6.79	1.25	4.24	1.42
Methylenechloride	3.98	0.20	9.34	0.55	8.99	0.15	4.74	2.77	3.69	2.36	4.82	1.57	4.21	0.51	7.25	3.97	7.25	3.97	11.15	1.09	11.22	1.02	7.68	2.29
Trichloroethane	6.63	0.22	12.99	1.23	11.88	0.37	6.68	4.31	4.53	1.87	3.25	1.35	6.01	1.76	10.40	5.38	10.40	5.38	18.02	0.86	17.70	1.55	11.44	3.97
1,2-dichloropropane	7.40	0.45	12.32	0.74	12.78	0.35	9.09	3.19	5.53	1.66	4.08	1.10	6.85	1.75	9.73	4.62	9.73	4.62	18.31	0.47	16.94	2.39	11.08	2.42
2,2-dichloropropane	5.31	0.61	11.63	0.66	11.87	0.55	7.28	3.56	5.16	2.23	4.17	2.92	5.77	0.34	10.57	1.37	10.57	1.37	20.56	2.18	19.95	4.12	11.03	4.22
Tetrachloroethane	6.57	0.69	14.71	2.92	13.01	0.57	8.03	4.19	6.22	1.74	7.93	4.79	8.40	1.79	13.14	5.11	13.14	5.11	23.58	8.51	22.60	5.16	13.70	4.73
trichloroethylene	8.60	0.93	19.61	1.47	18.89	0.62	14.15	5.35	6.21	2.21	6.71	1.87	8.70	2.66	15.14	8.10	15.14	8.10	26.48	1.83	24.09	2.98	16.29	3.97
Bromomethane	6.13	0.36	13.08	0.63	15.76	1.32	9.34	6.41	5.36	1.96	4.41	1.90	6.60	0.64	11.47	5.00	11.47	5.00	17.03	2.52	16.69	2.05	10.05	2.42
Ether VOC																								
Tetrahydrofuran	4.25	1.05	6.33	0.60	5.28	0.35	3.30	1.62	3.80	1.91	3.13	1.34	4.10	0.65	5.02	2.50	5.02	2.50	9.19	1.08	9.96	1.05	6.46	1.33
Isopropyl acetate	3.45	0.23	3.66	0.27	3.64	0.28	4.19	1.06	2.86	1.06	4.22	2.27	3.49	0.18	3.64	0.29	3.64	0.29	7.66	2.87	8.43	1.32	5.21	1.54
TERPINENE VOCs																								
α- pinene	2.08	0.26	4.54	0.78	3.31	0.40	2.52	0.50	2.01	0.77	2.44	0.76	2.04	0.34	3.27	1.43	3.27	1.43	5.79	0.83	6.98	0.09	4.38	2.30
β- pinene	1.51	0.32	2.32	0.55	2.57	0.45	4.64	4.35	4.18	3.27	3.13	1.65	4.31	4.77	2.80	1.22	2.80	1.22	8.27	0.98	8.58	0.68	5.49	2.51
Camphene	1.37	0.32	1.85	0.30	2.14	0.20	3.29	1.92	3.31	1.32	2.94	0.54	1.97	0.93	1.95	0.43	1.95	0.43	4.29	0.73	4.49	0.49	1.85	0.60

3.5 Principal Component Analysis (PCA) of VOCs

Principal component analysis is a method for the source identification of the materials of interest. It also provides a way of identifying patterns in data and expressing the data in such a way as to highlight their similarities and differences. Patterns in data can be hard to find in data of high dimension, where the luxury of the graphical representation is not available. Source identification analysis of particulate matter was performed using the principal component analysis method, which is widely used to factorize the input concentration data of different species having a linear relationship between total mass concentration and the individual concentrations [20].

Four (4) factors were extracted from the VOCs (Table 2), these components accounted for 84.67% in the total variation among the VOCs. Component 1, 2, 3 and 4 accounted for 67.88, 7.62, 5.02 and 4.17% respectively.

The rotated component matrix and components plot (Table 2 and Fig. 7) shows the correlation between the extracted components the VOCs, using an inclusion factor of 0.5. Component 1 was found to be more loaded with Ethanol (0.816), Benzene (0.683), Ethylbenzene (0.733), Naphthalene (0.807), n-Butyl benzene (0.870), n-Propyl benzene (0.814), Toluene (0.850), m+p-Xylene (0.828), o-Xylene (0.648), Styrene (0.800), Chlorobenzene (0.832), Chloroform (0.866), Carbon tetrachloride (0.814), Methylene chloride (0.932), Trichloroethane (0.921), 1,2-dichloropropane (0.924), 2,2-dichloropropane (0.844), Tetrachloroethane (0.827), Trichloroethylene (0.921) and α-pinene (0.754). Thus, component 1 is a blend of Ethanol, Aromatic VOCs, Halogenated VOCs, and Terpinene VOCs. Component 2 was more closely associated with Benzene (0.598), Ethylbenzene (0.504), Isopropylbenzene (0.850), o-Xylene (0.573), Isopropyl acetate (0.693) and β-pinene (0.907) i.e. component 2 is a blend of Aromatic VOCs, Ether VOCs, and Terpinene VOCs. Component 3 was more closely associated with Tetrahydrofuran (0.813) and Camphene (0.561). Thus component 3 is a blend of Ether VOCs and Terpinene VOCs. Component 4 was more closely associated with Bromomethane (0.905). Thus, component 4 is a blend of Halogenated VOCs only.

The principal component plot in rotated space is in agreement with the principal component analysis.

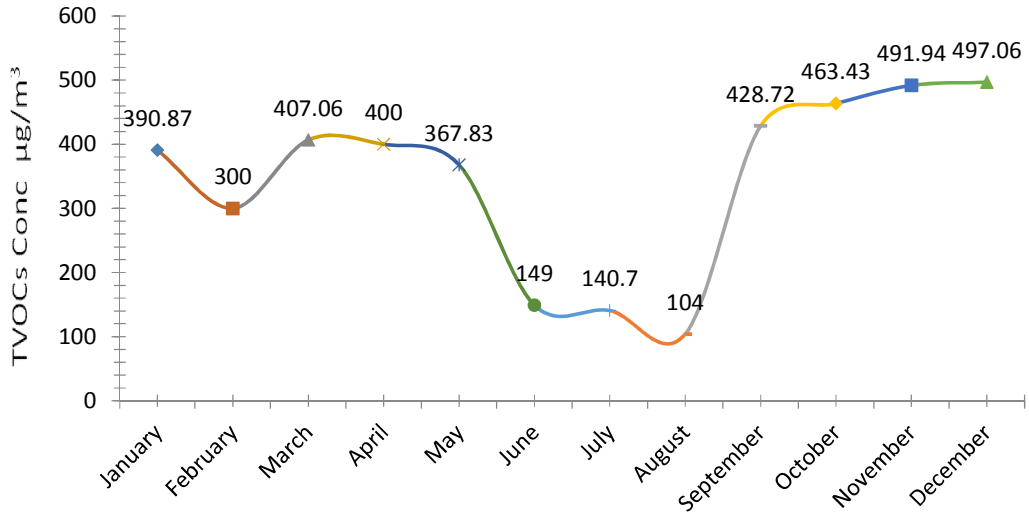

Fig. 6. Comparison of ambient concentrations of VOCs during the dry and wet season

Table 2. Rotated component matrix

Component	Component				Communality
	1	2	3	4	
Ethanol	0.816	0.446	-0.027	0.027	0.866
Benzene	0.683	0.598	-0.027	0.104	0.835
Ethylbenzene	0.733	0.504	-0.112	-0.012	0.804
Isopropyl benzene	0.174	0.85	-0.1	-0.026	0.764
Naphthalene	0.807	0.481	-0.05	-0.091	0.893
n-Butyl benzene	0.87	0.404	-0.069	-0.041	0.926
n-Propylbenzene	0.814	0.495	-0.019	0.094	0.917
Toluene	0.85	0.47	0.031	0.056	0.947
m + p-Xylene	0.828	0.158	0.168	0.051	0.742
o-Xylene	0.648	0.573	-0.163	-0.04	0.777
Styrene	0.8	0.373	-0.135	-0.085	0.805
Chlorobenzene	0.832	0.448	-0.078	-0.03	0.899
Chloroform	0.866	0.063	0.242	0.067	0.816
Carbon tetrachloride	0.814	-0.159	0.288	0.237	0.828
Methylenechloride	0.932	0.195	-0.107	0.104	0.930
Trichloroethane	0.921	0.267	-0.069	-0.084	0.932
1,2-dichloropropane	0.924	0.241	0.028	-0.085	0.920
2,2-dichloropropane	0.844	0.373	-0.003	-0.072	0.856
Tetrachloroethane	0.827	0.365	0.044	-0.07	0.823
Trichloroethylene	0.921	0.275	-0.066	0.025	0.929
Bromomethane	-0.033	-0.083	-0.103	0.905	0.837
Tetrahydrofuran	-0.122	-0.053	0.813	-0.167	0.707
Isopropyl acetate	0.493	0.693	0.096	-0.102	0.743
α-pinene	0.754	0.495	-0.112	0.129	0.843
β-pinene	0.185	0.907	0.158	-0.072	0.887
Camphene	0.393	0.457	0.561	0.337	0.792
Eigen value	17.648	1.980	1.304	1.083	
% of Variance	54.506	20.761	5.034	4.370	
Cumulative %	54.506	75.726	80.305	84.674	

Possible sources: Waste degradation, Waste combustion, Vehicular emission, Road traffic emission

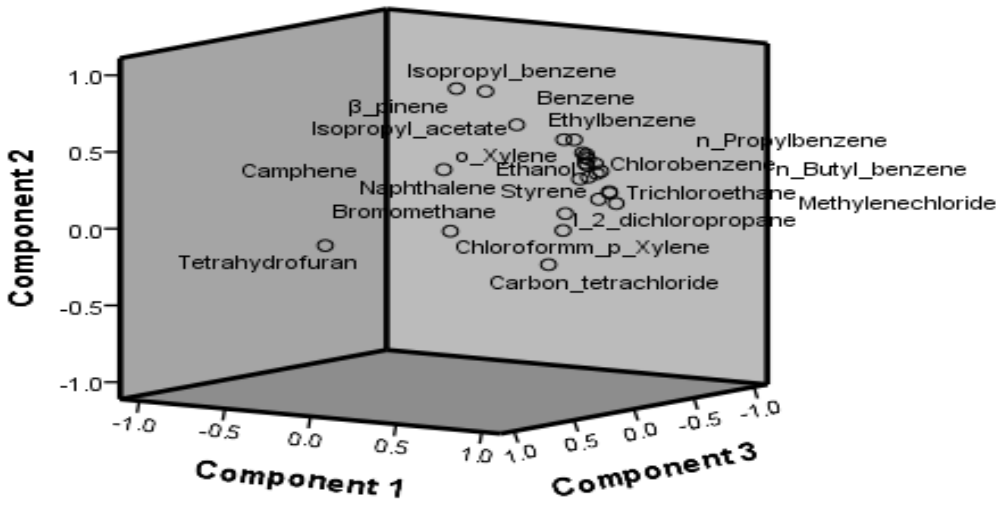

Fig. 7. Principle component plot in rotated space

4. CONCLUSION

The VOC concentrations in the ambient air of the Ikhueniro open dumpsite in Benin City were studied to understand the composition, distribution and seasonal variation. Twenty-six species of VOCs were quantified in forty-five weeks of sampling and displayed seasonal variations. The TVOC concentrations during the dry season were higher. The principal component analysis revealed that the major sources of VOCs in the open dumpsite are mainly anthropogenic. Therefore, municipal authorities and government agencies should intensify effort in controlling the air pollutant emission from open dumpsites by controlling open burning activities. Dumping of waste, scavenger's activities in the dumpsite and proper planning should be considered by the local authorities to reduce the associated particulate and VOC emissions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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