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Investigation of Ambient Aromatic Volatile Organic Compounds in Mosimi Petroleum Products Depot, Sagamu, Nigeria

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Abstract: Among chemical industries, petroleum depots have been identified as large emitters of Volatile Organic Compounds (VOCs).They affect air quality and constitute serious health and environmental problems on the ecosystem. Air samples were collected over activated charcoal, using a low volume air sampler. The sampler was placed at a human breathing height of 1.5 m for a sampling period of 8 hours at seven different sampling locations as follows; Workshop area, Slop Tanks area, Gate 1, Tank Farm area, Gate 2, Otiyelu Village and Marketer's Block. Desorption process was performed on the adsorbed activated charcoal using a solvent extraction method. The extracted solutions were subjected to Flame Ionization Detection analysis in a Gas Chromatograph using a capillary column HP 5MS with length, inner diameter and particle size set at (30 m × 0.25 mm × 0.25 µm). The Gas Chromatograph was powered with ChemStation RevA09.01 software to determine the concentrations of each of the VOCs species present. The sampling collection and quantitative analysis described above is consistent with ANSI/ASTM D-1605-60 procedure. The identified VOCs species emitted were characterized by toluene (52.84%), benzene (37.61%), xylene (5.67%), and ethyl benzene (3.88%). The observed concentrations uncovered the air tolerance limits set by United States Environmental Protection Agency and the Agency for Toxic Substances and Diseases Registry.

Keywords: BTEX; VOCs; Industrial Pollution; Occupational Exposure; Acute and Chronic Inhalation.

1. Introduction

Petroleum products depots are generally establish with large installations and equipment. Their routine operations are largely associated with emissions of various volatile organic compounds (VOCs) into the atmosphere mainly originated from distributions network, the storage facilities and waste areas (Muhibbu-din 2017, Kalabolakas *et al*. 2001). Although some VOCs are emitted from large sources but most are emitted from smaller multiple sources. The varieties of sources of emissions of VOCs are quite large (Muhibbu-din, 2017, De Nevers, 1995).

Novel technologies and subsequent pollutions are serious threats to the environment and public health (Khoshand et al. 2017). Benzene, toluene, ethyl benzene and xylene (BTEX) are the most typical aromatic component of VOCs in the air (Chattopadhyayy *et al*,1997; Srivastava *et al*.,2005).They are known for degrading air quality; their associated oxidants are threat to human health (life) and ecosystem.(Molina et al. 2007). Short term (acute) exposure adverse effect include conjunctive irritation, nose and throat discomfort, headache and sleeplessness, allergic skin reaction ,nausea, fatigue and dizziness. While long term (chronic) exposure adverse effect include loss of

co-ordination , leukemania, anemia, cancer and damage to liver, kidney and central nervous system (Kim *et al*., 2001; Pohl *et al* ., 2003; Kerbarchi *et al*. 2006). VOCs are commonly encountered by people as they go about their daily activities (Ojiodu *et al*., 2011) for both indoor and outdoor.

Researches have shown that VOCs enter the human bloodstream through inhalation, ingestion and through the skin (ATSDR, 2001) .Other effects of VOCs are recognized such as their contribution to stratospheric ozone depletion and enhancement of the global greenhouse effect (Cetin *et al*., 2003).

Studies on long-term monitoring of aromatic VOCs pollutants from industrial facilities confirm a significant exposure for inhabitants, workers and environment of these areas (Suleimanov 1997, Muhibbu-din, 2017). Once VOCs are emitted into the atmosphere, they cause not only pollution problem on local scale but also play an important role on regional scale like acid rain, photochemical ozone formation initiated by the reaction with OH radicals in the troposphere in the presence of nitrogen oxides and sunlight (Muhibbu-Din, 2017; Finlayson-Pitts and Pitts,1986).

Global concern regarding VOCs arise due to their ability of long range transport, distribution and accumulation in various component of environment, their toxic nature and significant contribution from industrial (anthropogenic) and natural (biogenic) sources (Srivastava etal.,2005).

There are number of researches on VOCs studies and monitoring. Rezazadeh *et al* (2011) probed occupational exposure of petroleum depot workers in Iran to VOCs emission. They revealed that toluene is the most abundant compound the workers are exposed to with valued of 0.2 - 0.27 ppm. A study of VOCs in Nigerian atmosphere by Ojiodu *et al* (2012) revealed that aromatic VOCs were found to be highest with 43% around a fishing lake of a rural community in Lagos State while Olumayede and Okuo (2011) also revealed 40% of aromatic VOCs among Total VOCs identified in high traffic within Benin City. Akeredolu and Sonibare (1997) investigated a Nigerian Refinery and its immediate environment and found that toluene is the most abundant VOCs emission with 0.434 mg/m^3.Table 3 in this research shows average concentrations of BTEX among cities in the world. This indicates that more aromatic VOCs are emitted from petroleum refineries and storage facilities compare to other sources like road, outdoor and indoor environments.

There are few studies that have reported VOC levels in Nigerian cities so far. Only a few works have been done for Nigerian refineries and very few attempts has been made to study ambient level of VOCs in a Nigerian petroleum depots. This study is an attempt to investigate and envisage the impact of presence of Mosimi petroleum products depot on workers of the petroleum depot, abut residence and host environment.

2. Methodology

The study area

Sagamu, the third largest settlement in Ogun state after Abeokuta and Ijebu Ode, is located within latitude 6°50' and 7°00' N and longitude 3°45' and 4°00' E in the land area of 614 km^2 . The area stands on a low-lying gently undulating terrain with altitude ranging between 30 and 61 m above sea level. The town is a semi-urban area with an estimated population of 200,000 people. It is located midway about 50 km northward from Lagos and southward from Ibadan. Sagamu is within the tropical humid climatic zone of Nigeria, which is generally characterized by high rainfall and high relative humidity. This is attributable to the prevalence of moisture laden tropical maritime air mass over the region for about nine months in a year. The mean relative humidity varies from 66.2 % in January to 88.4 % in July (Akanni, 2000). The rainfall shows a double-maxima distribution reaching the peak during the months of June and September. The average monthly rainfall for the study area ranges between 7.1 mm in the month of January to 208.3 mm in the month of June. The mean annual temperature is 26℃; although with some variations over time. The mean diurnal minimum temperature varies from 21.8 ℃ in December to 24.34 ℃ in April while the mean diurnal maximum temperature varies from 33.92 ℃ to 37.1 ℃ at the onset of the wet season (March and April) (Akanni, 2000).

On the basis of climatic features, the Sagamu is characterized by two distinct weather seasons: the wet and dry. The wet season marked by lower mean temperature, higher total rainfall and higher relative humidity is usually experienced between the months of February and October. However, little dry season is sometimes experienced in August, a phenomenon characterized by drastic reduction in the frequency and intensity of rainfall and referred to as 'August break'. The dry season sets in by November and persists till the end of January. It is

usually accompanied by harmattan cold, brought by the prevailing north-west winds.

Description of sampling site

Mosimi depot is one of the subsidiaries of Nigeria National Petroleum Corporation, located at Sagamu, Ogun state. The basic activities in Mosimi Depot are; reception of petroleum products such as, PMS, DPK, and AGO from Atlas Cove and local refineries. The Petroleum products are pumped to both Ibadan and Ore depots. Others activities that often take place include: quality control analysis of products (laboratory analysis), inter tank transfer, tank dipping and sampling, blending of an off-spec with on-spec products, fiscalization, calibration and stock taking activities.

The depot operates with a total number of 21 storage tanks designated with numbers of specifications. Tank 21, 16, 41, 42, and 43 are made for Premium Motor Spirits (PMS) with a total capacity of 19,200 m³ each, for tank 44,45,46,47 and 14, are for Dual Purpose Kerosene (DPK) with a total capacity of 19000 m³ each. Tank 51, 52, 53, 54, 55, 56 and 42 are made for Automotive Gas Oil (AGO) with a total capacity of 23, 0704 m³ each. Tank 71, 72, 73 and 74 are called "Slop tank" with a total capacity of 200 m³ each. The Depot pumped and received products via pipelines.

Sampling Locations

All units of the depot were categorized into seven locations as follows; Workshop area, Slop Tanks area, Gate 1, Tank Farms , Gate 2, Otiyelu Village and Marketer's Block. Each unit was deployed with sampling system over the survey period as shown in Figs1 and 2. The sampling system was placed at human breathing height of 1.5 m for a sampling period of eight (8) hours at different sampling units. The survey period was every day of the sampling campaign.

The Sampling System

This is made up of low volume air sampler, sampling sorbent tubes (adsorption column) and adsorbent media (activated charcoal).The air sampler is a chargeable battery powered device (capable of operating on battery for up to 10 hours) through which ambient air were sucked via adsorbent media.15g of activated carbon was filled in the adsorption tube with glass wool on one side of the adsorption tube. Air samples were pumped through at a fixed flow rate of 12.0 litres per minute. The adsorption column is a glass tube of length 20.0cm and 4.0cm in diameter. The lower end of adsorption column is a glass tube of length 7.0 cm with a diameter of 0.70cm. It was corked at the top with rubber while glass wool was used at the base as a support for adsorbent (activated charcoal).The lower end of the adsorption column was connected to the to the air sampler. Sampling period that was adopted was eight (8) hours .The sampling system was assembled at various locations site where sampling was carried out.

After sample collection in the field, the adsorbed activated charcoal were placed in sampling bottles and were preserved in ice blocks in a cooler before being taken to the refrigerator where they were kept until extraction and analysis time.

Extraction Procedure

Each sample was placed in the thimble of soxhlet extractor fitted to a reboiler flask containing about 75 ml of carbon disulphide *(CS_2)* that is solvent that was used for extraction. The flask was heated by heating mantle with a thermostat for temperature regulation of 50℃. The condenser for extraction was connected to CHURCHILL chiller which was maintaining the cooling fluid at preset temperatures in the range of -5℃ to 0℃. On attainment of this temperature; heating mantle was switched on and was regulated to a convenient point of 50℃. The sample extraction set-up was run last for about 4 hours for complete extraction. The extract was collected in a sampling bottle and was preserved in a refrigerator. Before further use, the soxhlet extractor and flask were cleaned .The process was repeated for every sample. For every run, new thimble was used in order to prevent contamination.

Sample (Chromatographic) Analysis

The quantitative determination of extracted solutions were analyzed with Gas Chromatography (Model: HP 6890) fitted with a Flame Ionizations Detector (GC-FID). The capillary column was HP 5MS with length, inner diameter and particle size set at (30 m×0.25 mm×0.25 μm) .It was attached to the injection port. The flow rate of carrier gas (hydrogen) was 1.0 mL/min; the hydrogen pressure and compressed air were set at 22 psi and 28 psi respectively. The injection temperature was split injection set at 150 ℃, the detector temperature at 320 ℃ , and the oven temperature was programmed

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at 50 ℃ with the 1st ramped 5 ℃/min to 150 ℃ and 2nd ramped at 10 ℃/min to 250 ℃ . A 1mL aliquot of the final solution was injected in the GC (split ratio; 20: 1). Calibration standards were supply by the Laboratory which was used for calculation of concentrations from chromatography peaks. Calibration standard was first run thereafter sample was run and quantifies by ChemStation software. The sampling collection and quantitative analysis describe above is consistent with ANSI/ASTM procedure. (ANSI/ASTM D-1605-60).

Figure 1: Geographical location of study area and Mosimi petroleum depot

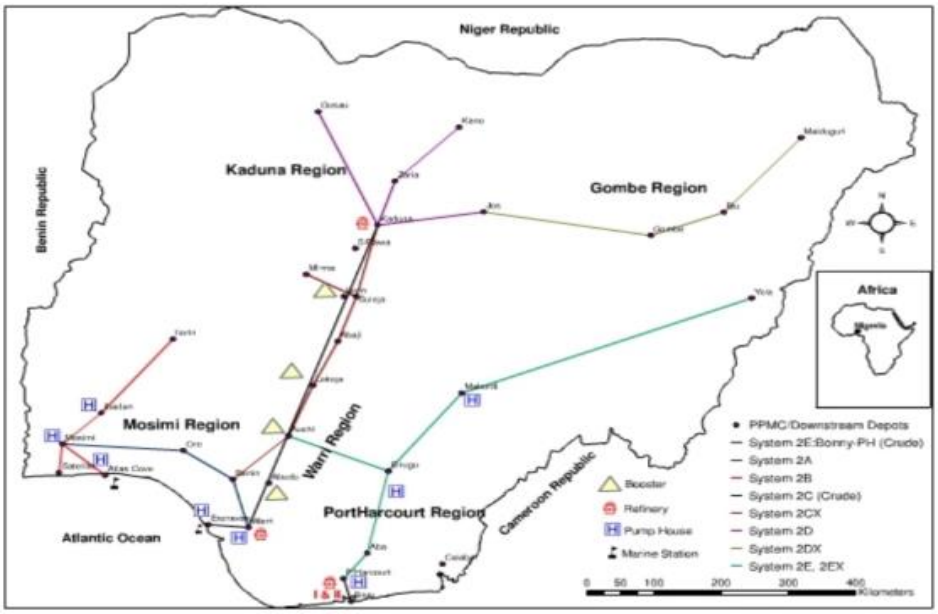


Figure 2: A map showing NNPC pipeline network (Nigeria) revealing the Mosimi Pipeline

3. Results

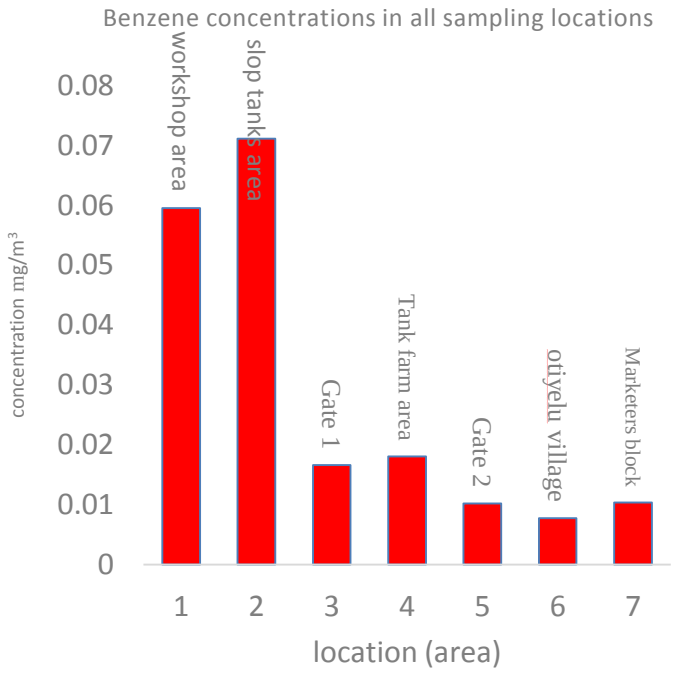
Benzene Concentrations

The concentrations of benzene, toluene, ethyl benzene and xylene were measured for air basin of Mosimi PPMC depot is summarized in Table 1.0. Benzene concentrations (37.61%) were recorded at various locations within and around the depot. Concentration of 71.12 µg/m^3 was recorded at Slop tanks area (located at east of the depot) was found to be the highest among sampling locations considered. Its location may be a contributing factor to high benzene concentration obtained. Other contributing factors may be ascribed to evaporative emissions from pipelines, Tank farm 21 and four slop tanks because of low height, presence of sludge from Tank Farm 22 (that has not be cleared) not too far from Slop tanks, variability of wind speed and so on contribute to high concentration of benzene in the slop tanks area.The Workshop area was located less than 1km from the loading gantry and also in the east of the depot. The benzene concentration of 59.54 µg/m^3 (second highest) was obtained at that site. The contributing sources to the concentration obtained may be due to proximity to loading gantry and decanting point and slop pit at the front, pumping pit at the back and bolster pump pit by the side of workshop. The location is characterized with high variable strong wind speed.

At Tank farms area, benzene concentration was found to be 18.08 µg/m^3. This value is low when compared to concentrations earlier discussed. It is located at west of the depot. Thus observation here could be attributed to good height of the Tank farms (emission takes place at the top roof of tank), no spillage or leakage of petroleum products as at the time of sampling was observed and prevailing wind direction prevent emissions depositing to the ground level.

The benzene concentration observed at Gate1 is 16.60 µg/m^3. The Gate 1 was characterized with high variable of wind speed. The contributing source may include loading gantry (due to proximity to Gate 1), vehicular emissions from loading trucks and other vehicle as they move into PPMC premises.

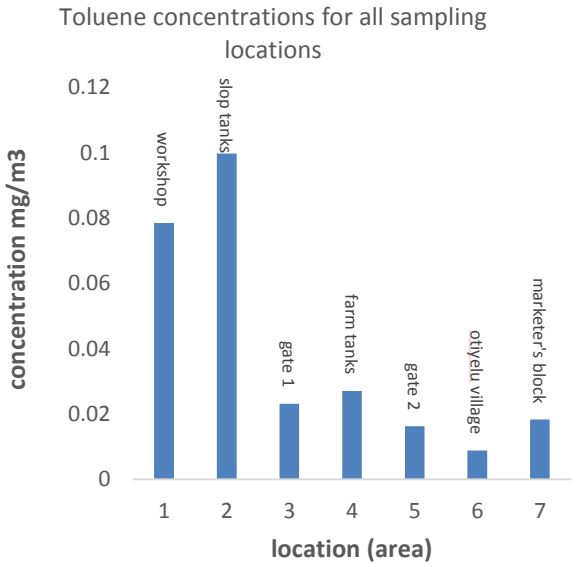
At Gate 2, the concentration of benzene is 10.22 µg/m^3.The contributing sources could be from separator pit, waste water from the depot and tank farms that contain remnants of DPK (Dual Purpose Kerosene). Low wind speed was experienced during air sampling. The benzene concentration observed outside PPMC Mosimi depot include one at marketer's block and the second at Otiyeju village (behind PPMC Area Office) are 10.37 µg/m^3 *and* 7.73 µg/m^3 respectively. For marketer's block, the contributing sources might include vehicular emissions and presence haulage (where excess products are drawn from loading truck) and emissions from the depot. Variable wind speed was experienced during air sampling. Marketer's block host good number of people and various kinds of vehicle at a time. Level of benzene concentration observed at Otiyeju village was at of 7.73 µg/m^3. This low level observed could be attributed to her far distance from the contributing sources. The village is located at a distance right behind area office of PPMC and east of the depot. The prevailing wind directions do not favour influx VOCs and may have limits VOCs species from getting deposited to the village.



Toluene Concentrations

Among VOCs species observed, toluene concentrations are the most abundance VOCs

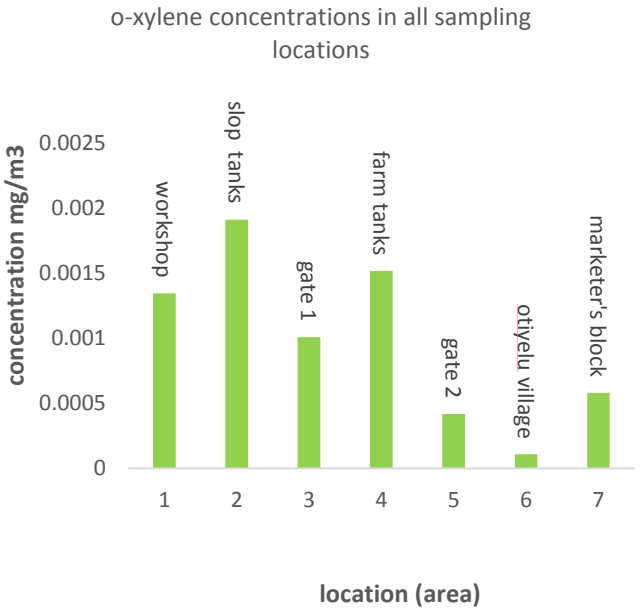
species in all sampling locations (52.84%). The maximum observed toluene concentration was 99.75 µg/m^3 at slop tank area. The occurrence of maximum concentration at Slop Tank area could be traced to explanations proffer to benzene concentrations. Within PPMC depot, toluene concentrations were in descending order of slop tank area (99.75 µg/m^3), Workshop area (78.53 µg/m^3), Gate1 area (23.16 µg/m^3), Tank Farms area (20.76 µg/m^3), Gate2 area (16.30 µg/m^3). Beyond PPMC Mosimi Depot premises toluene concentration decreases (marketer's block area: 18.34 µg/m^3 and Otiyeju village: 8.88 µg/m^3) due to wash down of little or low dispersed hydrocarbon vapour from the depot.

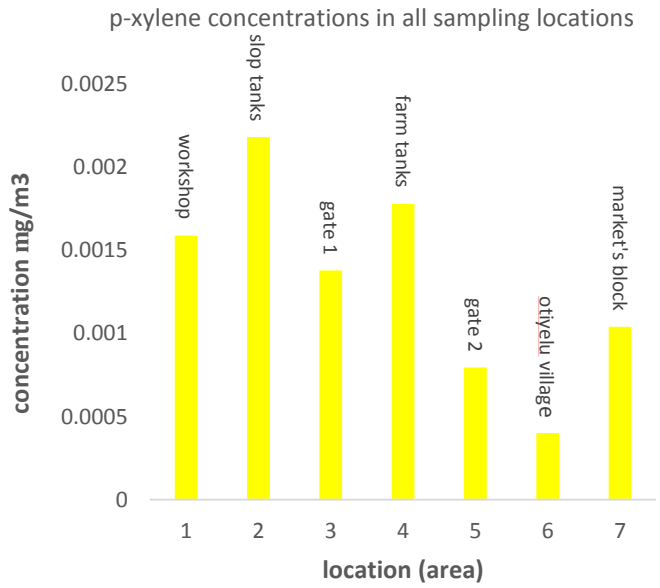


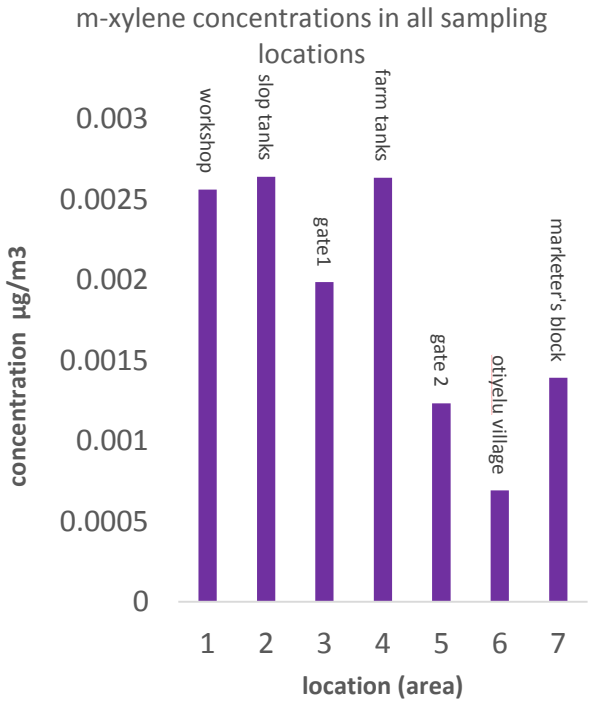
Xylene concentrations

The GC/FID analysis identified three isomers of xylene (5.67%). They are para-xylene (p-xylene), meta-xylene (m-xylene) and ortho-xylene (o-xylene). Unlike the earlier findings with benzene and toluene levels in terms of spatial distribution, Trace level of xylene concentrations were observed.

Among the three isomers of xylene, m-xylene is the most prominent. The m-xylene detected at Slop Tank area was seen to be highest (2.82 µg/m^3), followed by 2.56 µg/m^3 at Workshop area. The lowest concentration of m-xylene was 0.69 µg/m^3 at Otiyeju village. P-xylene concentration is next to m-xylene in descending order of distributions. The highest detected was at Slop Tanks area with concentrations of 2.18 µg/m^3 with the least at Otiyeju village with concentration of 0.40 µg/m^3. The least among the xylene isomer is o-xylene with highest concentration observed at Slop Tanks area with concentration 1.91µg/m^3 and least concentration was observed to be 0.11µg/m^3 at Otiyeju village. All xylene isomers detected are extremiuely at low value probably due to photochemical reactions.







Ethyl benzene concentrations

The concentrations of ethyl benzene for air basin of PPMC and its environment at various sampling location is the least amount among the VOCs species considered (3.88%). The maximum concentration recorded of ethyl benzene was at Slop Tanks area with 4.94 µg/m^3 while the least concentration was observed at Otiyeju village with 0.10 µg/m^3. The trends of ethyl benzene emission could also be traced to other VOCs species considered. Presence of ethyl benzene is as a result of hydrocarbon vapour from various sources in the depot.

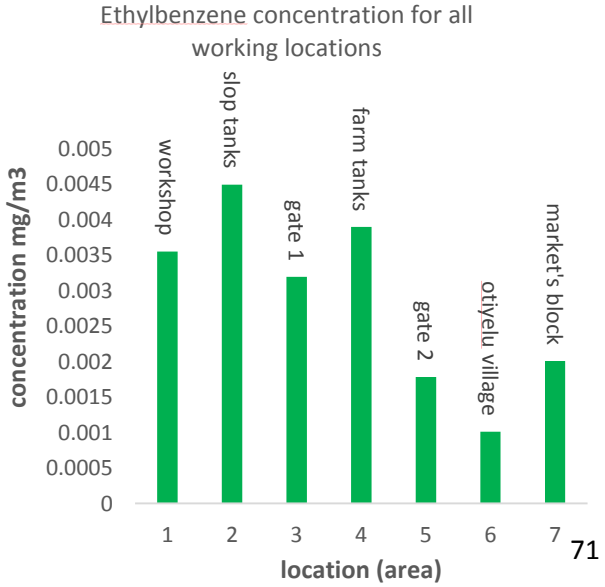


Table: Sum and average measured concentrations (µg/m^3) of VOCs species at Mosimi PPMC depot

	Location	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	Xylene
1	Workshop	59.54	78.53	3.55	1.59	2.56	1.34	5.49
2	Slop Tanks	71.12	99.75	4.49	2.18	2.64	1.91	6.73
3	Gate 1	16.6	23.16	3.2	1.38	1.99	1.01	4.37
4	Tank Farms	18.08	27.06	3.9	1.78	2.64	1.52	5.93
5	Gate 2	10.22	16.3	1.79	0.79	1.23	0.42	2.45
6	Otiyelu Village	7.73	8.88	1.01	0.4	0.69	0.11	1.2
7	Market's Block	10.37	18.34	2.01	1.04	1.39	0.58	3.01
	Summation	193.66	272.02	19.95	9.16	13.14	6.89	29.18
	Average	27.67	38.86	2.85	1.31	1.88	0.98	4.17
	standard deviation	26.20	35.35	1.27	0.61	0.79	0.65	2.02

Table 2: Comparison of average measured VOCs species concentrations (µg/m^3) with Air Quality Standards

S/N	VOCs species	USEPA chronic inhalation guidelines	ATSDR chronic inhalation guidelines	ATSDR acute inhalation guidelines	PPMC Mosimi depot sampled (averaged measured concentration)
1	Benzene	30	9.57	287.1	27.67
2	Toluene	400	300	3760	38.86
3	Ethyl benzene	1000	260	21680	2.85
4	p-Xylene	100	220	8670	1.31
5	m-Xylene	100	100	8670	1.88
6	o-Xylene	100	220	8670	0.98

Source: USEPA; Source: ATSDR 2017
For duration, Acute = 1to14 days and Chronic = 1 year or Longer

Table 3: Recent average concentrations µg/m^{3}of BTEX among cities in the world

Sampling site	Date	Sampling method	B	T	E	X	Reference
Thailand/Bangkok	2013	Active charcoal tube	49.7	31.7	3.8	33.2	Tunsaringkarn *et al* 2015
China/Guangzhou	/2011	Not Available	3.5	15.7	5.8	7.6	Zou *et al* 2014
Mexico/Monterrey	2013	Sorbent Tube	38.2	12.9	4.7	3.1	Cerón-Bretón *et al2014*
Indian /Nehru Marg	2005	Organic vapour sampler	68.27	45.62	6.36	16.74	Pandya *et al* 2005
This research	2015	Low volume air sampler	27.67	38.86	2.85	4.17	

4. Discussions

Comparing the sampled average concentrations of benzene as against international standards as shown in Table 2.0. The mean concentration of benzene is lower when compared to United State Environmental Protection Agency (USEPA) (Chronic inhalation guidelines) and Agency for Toxic Substances and Diseases Registry (ATSDR) (Acute inhalation guidelines) standards but higher when compared with ATSDR (Chronic inhalation guidelines). This implies that benzene emissions from PPMC Mosimi depot are within international standard limits and that operational routine of the depot can be said to be safe for workers, host environment and general public.

Comparing the sampled average concentrations of toluene as against international standards as shown in Table 2.0. The mean concentration of toluene is lower when compared to USEPA (Chronic inhalation guidelines), ATSDR (Acute inhalation guidelines) and ATSDR (Chronic inhalation guidelines), standards. This indicate that toluene emissions from PPMC Mosimi depot are within international standards limit and that operational routine of the depot can be said to be safe for workers, host environment and general public.

Comparing the sampled average concentrations of xylene isomers as against international standards as shown in Table 2.0. The mean concentrations of xylene isomers are lower when compared to USEPA (Chronic inhalation guidelines), ATSDR (Acute inhalation guidelines) and ATSDR (Chronic inhalation guidelines) standards. This indicate that xylene emissions from PPMC Mosimi depot are within international standard limits and that operational routine of the depot can be said to be safe for workers, host environment and general public.

Comparing the sampled average concentrations of ethyl benzene as against local and international standards as shown in Table 2.0. The mean concentration of ethyl benzene is lower when compared to USEPA (Chronic inhalation guidelines), ATSDR (Acute inhalation guidelines) and ATSDR (Chronic inhalation guidelines) standards. This indicate that ethyl benzene emissions from PPMC Mosimi depot are within international standard limits and that operational routine of the depot can be said to be safe for workers ,host environment and general public.

5. Suggested strategies to abate and control VOCs emission from petroleum products depots in Nigeria

VOCs emitted during crude oil and petroleum products terminal storage activities/operations have thepotential to be significant from health, environmental and economic perspectives. Controlling VOCs is a serious concern and major challenge with reasonable available treatment or control technology.

In any approved or established petroleum depots or refineries, identification of potential sources of VOCs emission at design stage can assist in adopting efficient control technology. Technological treatment is an efficient way for VOCs emission reduction. Technology treatment includes source reduction and end pipe emission treatment and currently more focuses are place on the latter.

End pipe emission treatments involve collection of hydrocarbon vapour through air extractors and subsequent treatment of diluted air (contaminated air) with control destructive devices such as catalytic incinerator/combustion, thermal incinerator, enclosed oxidizing flares and so on. Installation or provision of catalytic combustion can assist in complete destruction of emitted VOCs. (Chen and Zheng, 2004).

For Source reduction, all controlling valves in the petroleum depots or refineries should be equipped with live-loading packing. The flanges serving hydrocarbon streams can be equipped with expanding graphite. Seals and those with purge or drain end should be equipped with caps, blinded or plugged for VOCs emission reduction.

For area sources, tanks and other storage for petroleum products should always be covered. Floating roofs on storage tanks reduce the opportunity for volatization (NESREA, 2009).

The inner or outer floating roofs should be installed with primary and secondary seals respectively. Cracks and leaks should be avoided and water effluent must not be discharged into drain without prior treatment. Finally, Nigeria should develop a specific policy to tackle VOCs for both existing and newly approved petroleum products depots and refineries.

6. Conclusion

A field VOC measurement for Pipelines and Products Marketing Company (PPMC) Mosim depot, Sagamu, Nigeria was conducted for this study. Four aromatic species were identified and quantified in the petroleum storage industrial site with air samples taken from selected locations within the petroleum depot and host environment. The concentrations of benzene, toluene, ethyl benzene, p-xylene, m-xylene and o-xylene ranged between 7.73 – 71.12, 8.88 – 99.75, 1.01 – 4.49, 0.40 – 2.18, 0.69 – 2.64 and 0.11 - 1.91 µg/m^3 respectively.
The mean values were 27.67, 38.86, 2.85, 1.31, 1. 88 and 0.98µg/m^3 respectively. These identified species show substantial variations among selected locations most especially toluene and benzene. A prevalence flowing air mass in geographical location of the industrial site observed is responsible for rich dispersion and dilution of VOCs emission which resulted to extreme low concentrations hydrocarbon pollution. The concentrations of identified VOCs were comparable in all locations, suggesting minimal external influence. The averaged measured concentration of VOCs species sampled at PPMC Mosimi depot and Host Environment comply with international standards set by United States Environmental Protection Agency (USEPA) and Agency for Toxic Substances and Diseases Registry (ATDRS), for both acute and chronic inhalations. This study has established that routine operational activities of PPMC Mosimi depot are safe for workers, host environment and general public. Regular monitoring of VOCs level should be encouraged to assess the change of VOCs level in the airshed of Mosimi petroleum products depot. However further determination of occupational health effects by analyzing the level of VOCs in urine, blood and stool of workers of the depot and residents of host environment should be carried out.

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Conflict of interest

The author declare that there is no conflict of interests regarding the publication of this research.

References

Akanni C.O., 'Physical government in Ogun State; Local and Regional Perspective, Centre for Sandwich programme (CESAP)', Ogun State University, Ago-Iwoye. (2000).\

Akeredolu, F.A., and Sonibare, J.A., 'Ambient air measurements of Benzene, Toluene and Xylene (BTX) within a Nigerian Refinery and its environs by the Carbon Adsorption /GC-FID Techniques'. Journal of the Nigerian Society of Chemical Engineers, 16:123-132. (1997).

ANSI/ASTM Procedure D-1605-60, "Standard recommended practices for sampling atmospheres for analysis of gases and vapour". (1990). https://onlinelibrary.wiley.com/doi/full/10.1002/3527600418.amsampgase0011

ATSDR (Agency for Toxic Substances and Disease Registry),' Toxicological profile for Toluene'. PB/95/100228/AS. US Department of Health and Human Services, public health service. 2015 http://www.atsdr.cdc.gov/toxprofiles/tp116.html

ATSDR.," Agency for Toxic Substances and Disease Registry, Minimal Risk Levels "(MRLs). 2015 https://www.atsdr.cdc.gov/mrls/index.asp

ATSDR (Agency for Toxic Substances and Disease Registry). "Toxicological Profile for Toluene" (Update). PB/95/100228/AS.US Department of Health and Human Services, Public Health Service. 2000. http://www.atsdr.cdc.gov/toxprofiles/tp116.html

ATSDR," Interaction Profile of Benzene, Ethyl benzene, Toluene and Xylene (BTEX)" (Draft for public comment), Atlanta: Agency for Toxic Substances and Diseases Registry, U.S Dept of Health and Human services. 2001 https://www.atsdr.cdc.gov/interactionprofiles/ip05.html

Chattopadhyay, G., Samanta ,G., Chatterjee S, Chakroborti,P.," Determination of benzene, toluene and xylene in ambient air of Calcutta for three years during winter". Environ.Technol. 18:211–218. (1997).

Cerón-Bretón J G, Cerón-Bretón R M, Kahl J D W, et al. Diurnal and seasonal variation of BTEX in the air of Monterrey, Mexico: preliminary study of sources and photochemical ozone pollution[J]. Air Quality, Atmosphere & Health (2014): 1-14.

De Nevers, N.," Air Pollution Control Engineering". McGraw Hill. Discusses various features of air pollution engineering (pollution control techniques, NOxchemistry, plume dispersion) (1995)

Kalabokas, P. D., Hatzianestis, J., Bartzis, J. G. and Papagiannakopoulos, P., Atmospheric concentrations of saturated and aromatic hydrocarbons around a Greek oil refinery, *Atmospheric. Environent* 35(14), 2545–2555. (2001)

Kerbachi, R., Boughedaoui, M., Bounoue, L., and keddam, M. "Ambient Air pollution by Aromatic hydrocarbons in Algiers". Atmospheric Environment; 40:3995-4003. (2006)

Brocco D.; Fratarcangelli R.; Lepore L.; Petricca M.; Ventrone I.," Determination of aromatic hydrocarbons in urban air of Rome". Atmos Environ. 31:557–66 (9 pages). (1997) https://dx.doi.org/10.1 016%2FS1352-2310(96)00226-9

Cetin, E. ; Odabasi, M. ; Seyfioglu, R., "Ambient volatile organic compound concentration Around a petro-chemical complex and petroleum refinery". Sci. Total Environ. 55:197-199 (3 pages). (2003) https://www.ncbi.nlm.nih.gov/pubmed/12873403

Chen, M., and Zheng, X. M.,"The effect of K and Al over NiCO2O4 catalyst on its character and catalytic oxidation of VOCs". Molecular Cellular Toxicology, 221:77-80. (2004)

Chin L. C.; Hung, Y. F.; Chi-Min S., "Source location and characterization of volatile organic compound emissions at a petrochemical plant in Kaohsiung, Taiwan". Air and waste management Association, 10:121-125 (4pages) (2005). https://www.ncbi.nlm.nih.gov/pubmed/16295274

Clayton, L.D.; Woodall, G.M.," A review of the mutagenicity and rodent carcinogenetic of ambient air". Mutation Research. 636 (1):36-94. 2007 https://www.ncbi.nlm.nih.gov/pubmed/17451995

Dybing, E.; O"Brien, J.; Renwick, A.G.; Sanner, T., "Risk assessment of dietary exposures to compounds that are genotoxic and carcinogenic" – An over view. Toxicology letters, 180(2):110-117 (7 pages). (2008). https://www.ncbi.nlm.nih.gov/pubmed/18584977

Federal Ministry Petroleum. NNPC crude oil and product pipeline network. (2014) https://www.slideshare.net/TransformNG/ministry-of-petroleum-resources

Finlayson- Pitts, B.;Pitts J., Jr.," Atmospheric chemistry: fundamental and experimental technique", New York, Wiley Inter-Science. 1986. https://searchworks.stanford.edu/view/1202278

Finlayson-Pitts, B.J.; Pitts, J.N., "Chemistry of the upper and lower atmosphere". Academic Press, San Diego. (2000). https://www.ncbi.nlm.nih.gov/pubmed/12873403

Gelencsér A; Siszler K.; Hlavay J., "Toluene–benzene concentration ratio as a tool for characterizing the distance from vehicular emission sources". Environ. Sci. Tech., 31: 2869 – 2872 (3 pages). (1997). https://pubs.acs.org/doi/abs/10.1021/es970004c doi: 10.1021/es970004c.

Kean, A.J.; Grosjeans, E.; Grosjeans, D.; Harley, R.A.," On- road measure of carbonyls in California light duty vehicle emissions". Environmental Science and Technology, 35: 4198-4204 (6 pages). (2001) https://europepmc.org/abstract/med/1171833

Kerbachi, R.; Boughedaoui, M.; Bounoue, L.; keddam, M., Ambient air pollution by Aromatic hydrocarbons in Algiers. Atmospheric environment; 40:3995-4003 (8 pages), (2006).

Kim, Y.M.; Hamad, S.; Harrison, R.M., Concentrations and sources of VOCs in urban and public micro environments. Environment Science Technology. 35(6), 997-1004 (7 pages) (2001). https://pubs.acs.org/doi/abs/10.1021/es000192y.

Khoshand A, Shahbazi Sehrani M, Kamalan HR, Bodaghpour S. 2017, Prediction of Ground-Level Air Pollution Using Artificial Neural Network in Tehran, Anthropogenic Pollution, 1 (1), 2017: 61-67. DOI: 10.22034/apj.2017.1.1.6167.

Lee, S. C.; Chiu, M.Y.; Ho, K.F.; Zou, S. C.; Wang, N.,"Volatile organic compounds (VOCs) in urban atmosphere of Hong Kong". Chemosphere 48(3): 372-382 (10 pages), (2002).. https://www.sciencedirect.com/science/article/pii/S0045653502000401

Lee, SC.; Chiu, MY; Ho, K.F.; Zou, SC. and Wang, X.,." Volatile Organic Compounds (VOCs) in urban atmosphere of Hong Kong". Chemosphere 48(3): 372-382 (10 pages) 2002. http://europepmc.org/abstract/MED/12146626

Millet, D.B.; Goldstein, A.H.; Allan, J. D., "Volatile organic compound measurement at aerosol residence times". Journal of geophysical research atmosphere, 109: 23 – 29 (6 pages). 2004. https://agupubs.onlinelibrary.wiley.com/doi/abs/10029/2003JD004026%4010.1002/%28ISSN%292169-8996.ITCTPEACE1

Molina, L.T., Kolb, C.E., Defroy, B., Lamb, B.K., Brune, W.H., Jimemez, J.C., Ramos-Vikegass, R., Saarmiento,J., Paramo –Figueroa V.H., Cardenas, B., Gutiernez –Aveday,V,. andMolina,M.I.

"Volatile organic compounds in Urban and Industrial Atmosphere: Measurement techniques and data Analysis". International Journal of Environmental Analytical chemistry, 83:199-217, (2007).

Muhibbu-din, I.E., "Investigation of ambient volatile organic compounds in Mosimi petroleum products depot, Sagamu, Nigeria". M.Sc Thesis Ladoke Akintola University of Technology, Ogbomoso. (2017).

Nelson P.F.; Quigley S.M.,"The m, p-xylenes: ethylbenzene ratio. A technique for estimating hydrocarbon age in ambient atmospheres". Atmos Environ. ; 17: 659 – 662 (3 pages), (1983). www.sciencedirect.com/science/article/pii/0004698183901415?via%3Dihub

NESREA," National Environmental Standards and Regulations Enforcement Agency Air Quality Guideline", (2009).

Ojiodu, C.C.; Okuo, J.M.; Olumayede, E.G," Background level of VOCs in rural fishing community of take, Lagos state, South Westerner, Nigeria". Journal of Science and Technology.58 - 63 (5 pages). (2011). https://www.ajol.info/index.php/ejesm/article/view/96667.

PANDYA G.H. , A.G. GAVANE, A.D. BHANARKAR AND V.K. KONDAWAR Concentrations of volatile organic compounds (VOCs) at an oil refinery. International Journal of Environmental Studies, Vol. 63, No. 3, June 2006, 337–351

Prinn, R.; Cunnold, D.; Rasmussen, R.; Simmonds, P.; Alyea, F.; Crawford, A.; Fraser, P.; Rosen, R., "Atmospheric trends in methyl chloroform and the global average for the hydroxyl radical ". Science 238: 945 –95 (50 pages), (1987). http://europepmc.org/abstract/MED/178293600

Quiram, E.R.; Biller, W.F.," Determination of trace quantities at hydrocarbons in the Atmosphere". Analytical chemistry, 30(7):1166-71(1958). https://pubs.acs.org/doi/abs/10.1021/ac60139a001

Rezazadeh, M. A.; Naghavi, Z .K. Zayeri, F.; Salehpour, S.; Seyedi, M.D.,"Occupational exposure of petroleum depot workers to BTEX compounds". International Archive of Applied Sciences and Technology. Volume 3 [2]: 92 – 96 (4 pages), (2012). https://www.semanticscholar.org/paper/Occupational-exposure-of-petroleum-depot-workers-to-Azari-Konjin/9707550d107e5ca841c6b782171c0c36a28337db

Rnlgesh, K., Singh, Ramteke, D.S.; H.D.; Juneja,; Pandya, G.H., "Ambient air Quality monitoring in terms of volatile organic compounds (VOCs) Occupational Health Exposure at petroleum refinery". International Journal Environmental Protection, 6:40-49 (9 pages),(2013). www.academicpub.org/DownLoadPaper.aspx?PaperID=4217

Singh, A.K.; Neetu, T.; Jain, C.l., "Concentration of Volatile Organic Compounds (VOCs) in urban atmosphere of National Capital, Delhi, India". International Journal of Pharmaceutical, Chemical and Biological 2(2), 159-165 (10 pages), (2012). www.ijpcbs.com/files/volume2-2-2012/6.pdf

Srivastava, A., Joseph, A.E., Patil, S., More, A., Dixit, R.C., Prakash, M., "Air toxics in ambient air of Delhi". Atmos Environ. 2005; 39:59–71. (2005). doi: 10.1016/j.atmosenv.2004.09.053

Srivastava, A.; Sengupta, B.;Dutta, S.A., "Source apportionment of ambient VOCs in Delhi City". Sci. Total Environ. 343: 207 – 220 (13 pages). (2005). doi: 10.1016/j.scitotenv.2004.10.008.

Srivastava, A,; Joseph A.E,; Devotta S., "Volatile organic compounds in ambient air of Mumbai-India". Atmos. Environ. 40: 892–903 (11 pages). (2006). https://www.researchgate.net/publication/223035813

Srivastava, A.; Sengupta, B. Dutta, S.A., "Source apportionment of ambient VOCs in Delhi city". Sci Total Environ. 343: 207–220 (13 pages), (2005). doi: 10.1016/j.scitotenv.2004.10.008.

Suleimanov, R.A., "Comparative characteristics of atmospheric emissions from petrochemical and petroleum processing industries". NII Med. Truda I Ekol. Cheloveka, Ufa, Russia. Gig Sanit.1:8–10 (2 pages). (1997). http://europepmc.org/abstract/MED/9081889

Tunsaringkarn T, Prueksasit T, Morknoy D, et al. Seasonal and spatial variation of ambient air volatile organic compounds in pathumwan district,Bangkok, Thailand[J]. J Health Res 29 (2015): 135-142.

United State Environment Protection Agency (EPA),"Regional Approaches to improving Air Quality particulate matter". 200l. www.epa.gov/oar/oaqps/airtrans/pm. html.

United State Environmental Protection Agency, IRIS Assessments 2018, Website; http //www.epa.gov/iris/htm

US-EPA, Air trends. Website;http://www.epa.gov/airtrends/ozone/htm.

Zou Y, Deng X, Li F. Health risk assessment of atmospheric benzene compounds in Guangzhou. Journal of Environment and Health 12 (2014): 1079-1081.

Zhonghua, L.; Dong, W.; Sheng, Z.Y.," DNA damage and changes of antioxidative enzymes in chronic benzene poisoning mice". Bing ZaZhi 21: 423 - 425 (2 pages), (2003). https://www.ncbi.nlm.nih.gov/pubmed/1476135