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Safety Evaluation of Volatile Organic Compounds (VOCs) in the Environment and Ready-to-eat Foods during Dry and Wet Seasons in Parts of Port Harcourt City, Rivers Sate, Nigeria

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Abstract Safety implications of the presence of Volatile Organic Compounds (VOCs) in the environment and selected ready-to-eat foods were investigated to determine the impact of wet and dry seasons on food safety in some parts of Port Harcourt. The study was carried out using complete randomized block design in three (3) factorial experiment. The experiment was conducted in dry and wet seasons along the 3 locations (Makoba-station 1, Elekahia-station 2 and Rivers State University-station 3). The Six Food products investigated were roasted plantain, roasted fish, roasted yam, suya, meat pie and doughnuts were purchased from parts of Port Harcourt city respectively. The results showed that VOCs value was highest (19950 $\mu g/m^3$) at station 1 during the dry season and as low as 1471 $\mu g/m^3$ during the raining season at station 1. VOCs level was higher in station in 2 and 3 (14817 and 15283 $\mu g/m^3$) during the dry season compared to lower values of (700 and 1086 $\mu g/m^3$) for station 2 and 3 during wet season respectively. No volatile organic compounds was detected in the street vended food samples during the raining season. However, Ethyl Benzene ($2.3x10^6$ ng/ul and 2.0 $3x10^6$ ng/ul) were detected in doughnut from station 3 and 1 during the dry season. The impact of factorial interaction of season and location on the presence of Volatile Organic Compounds in ambient air (VOCs) and vended street foods were significant (P<0.05).The presence of Volatile Organic Compounds in street vended foods is a source of health concerns.

Keywords: *food safety, volatile organic compounds, wet and dry season, ready-to-eat foods*

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1. Introduction

The City of Port Harcourt is home to many Oil and Gas industries in the Niger Delta, South-South, Nigeria. This sector also provided several distribution channels such as the exploration and production facilities, Liquefied Natural Gas (LNG) Plants, depots, filling stations and trucks transportation by land and barges by sea in Rivers State. These activities, products and services and its interaction with the environment produces a significant environmental aspects. One of such by-products is the release of volatile organic compounds (VOCs) into the environment. According to Lesa and Wageh [1]. Chemical contamination is a global food safety issue. There are many potentially toxic substances in the environment which may contaminate foods consumed by people. They include inorganic and organic substances and may originate from a wide range of sources such as industry and others, however, the environment is the major pathways for releases of these contaminants such as air, food, water and soil. Toxic volatile organic compounds (VOC), like benzene, toluene, ethylbenzene and xylenes (BTEX), are atmospheric pollutants representing a threat to human health. They are released into the environment from mobile sources in urban settings, but newly polluted areas are gaining importance in countries where accelerated industrialization is taking place in suburban or rural settings [1]. Benzene, toluene, ethylbenzene and xylenes (o-, m- and p-) are found in natural form in crude oil, diesel and gasoline, so they are released into the environment whether or not these fuels are burned. This is applicable to Port Harcourt environment with refineries, Petrochemicals, Downstream distribution networks and all associated oil and gas service providers.

Workers around these installations are known to patronize ready-to-eat foods to meet their food requirements. Street food vending has become an important public health issue and a great concern to everybody [2]. “Street foods are ready-to-eat foods and beverages prepared and/or sold by vendors and hawkers especially in streets and other similar public places" [3]. The improper food handling practices have been attributed to lack of adequate food safety knowledge. Thus, determining the level of food safety knowledge, practice and educating food establishment employees who handle food on proper food safety practices is crucial in preventing food borne illness arising from chemical contamination, though not acute but chronic in nature. The poor attitude of food handlers in managing waste arising from food packaging materials has also constituted another environmental menace as these materials (plastics) have been deposited into water bodies through drainages. The impact of these environmental nuisance is more evident for hawkers who walk distances along the streets of PH to sell their goods and services for their daily living.

For instance Petrol contains volatile organic compounds (VOCs) that evaporate in storage tanks. During unloading of petrol to an underground storage tank or refueling of trucks of a vehicle, petrol vapor in the tank will be displaced by the incoming petrol. At gantry, where operators discharge products into trucks, a lot of fugitive's emission takes place. These emissions are dispersed into the surrounding environment with its attendant risk. According to Ilaria *et al.*, [4]. Unless controlled, the petrol vapors will dissipate into the atmosphere. Major harmful effects of VOCs from petrol filling stations and depots would include :(a) Enhancing the formation of ozone and fine particulates in the atmosphere, thus causing smog (b) Presenting a potential health risk to the public as it contains benzene, a carcinogen, and (c) a nuisance to people in the vicinity. These pollutants are released into the surrounding environment, where local communities co-exist with the oil and gas facilities such as Bundu - Ama and Makoba in Port Harcourt terminal respectively. These communities do not have the capacity to identify, address, and evaluate their own health concerns on an ongoing basis, using data to guide and benchmark efforts. As a result, healthy communities that has this capacity for hazard identification and assessment is safe, economically secure, and environmentally sound, as all residents have equal access to high quality educational and employment opportunities, transportation and housing options, prevention, healthcare services, and healthy food and physical activity opportunities, (Health Resources in Action, [5]. However, this is not the case with Makoba and Bundu-Ama communities respectively, as they do not have the capacities to identify, assess and control the risk to an acceptable level. These communities are indeed vulnerable to associated hazards emanating from oil and gas activities with respect to the patronage of vended street foods and other allied industries activities, products and services.

For this study, the scope of Volatile Aromatic/Organic Compounds is limited to **(**BTEX) which is an acronym for benzene, toluene, ethyl benzene, and xylene. These compounds are some of the volatile organic compounds (VOCs) found in petroleum derivatives such as petrol (gasoline). Toluene, ethyl benzene, and xylene have harmful effects on the central nervous system. BTEX compounds are notorious due to their contamination of underground water especially near petroleum and natural gas production sites, underground storage tanks (USTs) or above-ground storage tanks (ASTs), containing gasoline or petroleum-related products, [6]. According to USEPA [7], BTEX are highly used in the industry as additives and precursors of other substances: benzene is used in the manufacturing of synthetic materials and consumer products, including plastics, nylon, insecticides and paints; toluene is used as solvent for paints, coatings, rubbers, oils and resins; ethylbenzene may be found in paints, plastics and pesticides, and it is also used as additive for aviation fuel; xylenes are used as solvent in the printing, rubber and leather industries.

Volatile organic compounds (VOCs) are part of the large hydrocarbon family, a vast array of aliphatic, aromatic hydrocarbons, their halogenated derivatives, alcohols, ketones and aldehydes [8], "VOCs have a property of conversion into vapour or gas without any chemical change. They are highly reactive hydrocarbons and participate in atmospheric photochemical reactions. Some of them have negligible photochemical activity; however they play an important role as heat trapping gases in atmosphere" According to Anjali and Dipanju, [8]. All organic compounds of anthropogenic nature, other than methane, those that are capable of producing photochemical oxidants by reacting with nitrogen oxides in the presence of sunlight are VOCs of both primary and secondary origin in ambient air have immense importance as they have direct as well as indirect effects on climate change, ecology and human health. Many VOCs are of natural origin, while many owe their existence to anthropogenic activities. [9]. Natural sources of VOCs include forests, termites, oceans, wetlands, tundra and volcanoes. Estimated global emission rate of biogenic VOCs is 1150 Tg yr-1 [9]. The anthropogenic sources of VOCs consist of vehicular emissions, petroleum products, chemicals, manufacturing industries, painting operations, varnishes, coating operations, and consumer products, petroleum handling, auto refinishing, cold clean degreasing, printing inks, dry-cleaning agent etc. VOCs are cause of concern firstly due to its role in formation of ground level ozone and smog and secondly due to some of them being carcinogenic, mutagenic and teratogenic in nature. Adverse effects of ozone on human health, crop viability and yields are well documented. Wide range of VOCs, imply wide range of reaction rates, which means large range of transport distances. Many VOCs have low reactivity and thus long atmospheric life times and can be classified as Persistent Organic Pollutants (POPs). Some VOCs are Hazardous Air Pollutants (HAPs) by virtue of their toxicity [10].

International concerns regarding VOCs arise due to their ability of long range transport, distribution and accumulation in various components of environment, their toxic nature and significant contribution from natural sources. Ambient air monitoring of VOC is aimed to control or avoid adverse impacts on humans and ecology. This should also result in knowledge of types and category of VOCs in terms of photochemical ozone creating potential of VOCs, concentrations of VOC species, their dispersion routes and fate in environment. The VOCs play an important role in the depletion of O_3 in the stratosphere, they can induce greenhouse effects, and they can serve as precursors of ground-level photochemical formation of O_3. Some VOCs can pose potential risks to human health. For example, benzene and 1, 3-butadiene have been linked with increases in diseases such as leukemia; formaldehyde is classified as a potential nasal carcinogen agent; while the polycyclic aromatic hydrocarbons are considered as potential lung cancer inducing agents [11,12], VOCs are emitted from both natural (vegetation, specifically rural forested areas, soil microbiota and geological hydrocarbon reservoirs) and anthropogenic (transport sector, industrial solvent use, combustion processes) sources [10,13]. The traffic emission is the main source of VOCs in the urban areas. This study evaluated the impact level of these VOCS variations on Vended street food as well as in the environment where these foods are on display

2. Materials and Methods

2.1. Study Area

Port Harcourt lies along the Bonny River and located in the Niger Delta, South-South part of Nigeria. Port Harcourt city covers about 360 sqkm. Port Harcourt is the capital and largest city in River State, located between the latitudes of 4°46'38.71" N and longitudes 7°00'48.24" E. As at 2016, the Port Harcourt urban area has an estimated population of 1,865,000 inhabitants, up from 1,382,592 as of 2006 [14]. The Study was conducted in three selected parts of Port Harcourt metropolis, Rivers States, along the following sampling points: Station1-Makoba (Terminal and Depots Housing Oil and Gas, and slump environment), Station 2- Rivers State University gate (Academic and Urban Environment) and Station 3-Elekahia (Urban- Industrial and Residential Area).

2.2. Methods

2.2.1. Experimental Design

Six (6) food samples each were purchased from the 3 (three) locations in Port Harcourt metropolis for two different days respectively and were wrapped with an aluminum foil paper, and transported to Rofnel Energy Services, Food Chemistry and Environmental Laboratory located at Plot 2 Adison Close, Rumuagholu, Port Harcourt, Rivers State, Nigeria same day for analysis. The whole study was done using complete randomized design in a factorial experiment. Three factorials were used (Factors A, B and C); factor A represented Season, B Location and C Street Vended food samples given as 2X3X6 factorials. The vended foods are as shown in Table 1. Using the previous method of Oyet et al. [15].

2.2.2. Sample Collection

A total of 18 (Eighteen) food samples consisting of roasted fish, roasted plantain, roasted yam, Meat Pie, Suya and Doughnut were purchased from roadside food vendors and hawkers along the Rivers State University Gate, Makobar-Industrial settlement, and Elekahia—Urban dwellers, with 3 (three) filter papers all in Port Harcourt city, Rivers State, Nigeria. Three (3) samples were collected along the three (3) different locations for two (2) day during each season. They were wrapped in an aluminum foil, placed in a cooler and taken to the laboratory from which sub-samples were obtained for the determination of Volatile Organic Compounds (VOCs). The choice of the samples were carefully made to reflect the most consumed street vended foods in Port-Harcourt. The samples were stored at 4 °C prior to analysis.

Table 1. Experimental Design: Season, Locations and Food Samples

SEASON	STATION 1	STATION 2	STATION 3
Raining & Dry	RP1	RP2	RP3
	RF1	RF2	RF3
	RY1	RY2	RY3
	SY1	SY2	SY3
	MP1	MP2	MP3
	DN1	DN2	DN3

Legends:
RP1 = Roasted plantain from Makobar, Port Harcourt
RP2 = Roasted plantain from Elekahia, Port Harcourt
RP3 = Roasted plantain from Rivers State University, Port Harcourt
RF1 = Roasted fish from Makobar, Port Harcourt
RF2 = Roasted fish from Elekahia, Port Harcourt
RF3 = Roasted fish from Rivers State University, Port Harcourt
RY1 = Roasted yam from Makobar, Port Harcourt
RY2 = Roasted yam from Elekahia, Port Harcourt
RY3 = Roasted yam from Rivers State University, Port Harcourt
SY1 = Roasted suya from Makobar, Port Harcourt
SY2 = Roasted suya from Elekahia, Port Harcourt
SY3 = Roasted suya from Rivers State University, Port Harcourt
MP1 = Baked meat pie from Makobar, Port Harcourt
MP2 = Baked meat pie from Elekahia, Port Harcourt
MP3 = Baked meat pie from Rivers State University, Port Harcourt
DN1 = Fried dough nut from Makobar, Port Harcourt
DN2 = Fried dough nut from Elekahia, Port Harcourt
DN3 = Fried dough nut from Rivers State University, Port Harcourt
Source: Oyet et al., [15].

2.2.3. Determination of Volatile Organic Compounds (VOCs) in the Environment

The air samples used for VOCs analysis were sampled by active method described by Demeestere et. al**.**, [16]. Using portable gas monitor that was calibrated before and after each sampling campaigns. An aeroqual environmental gas electromagnetic light monitor series 930 -IP65 equipped with infrared absorption sensor was used for the measurement of VOCs. The equipment was operated on the principle of dual wavelength IR absorption; the range of detection was between 0.1-1000 mg/m3 with alarm set at 0.20 and 50.00 mg/m^3 [17]. Measurements were done by holding the sensor to a breathing height of about 1.5 meter in the direction of the prevailing wind, readings were recorded when the monitor had warmed up (3minutes) to burn off contaminants on the sensor and air sucked into the sensor. The portable gas monitor obtained from Rofnel Energy Services Limited located at Plot 2 Addison Close, Rumuagholu, Port Harcourt.

2.2.4. VOCs (BTEX) Analysis in Street Vended Food Samples

The analysis for food samples were carried out with the Gas Chromatography- MS ASTM D5790 - 95 according to the methods of **APHA** [18]. GC-MS was obtained from Rofnel Energy Services Limited located at Plot 2 Addison Close, Rumuagholu, Port Harcourt, Rivers State, Nigeria.

2.3. Data Analysis

The mean values were subjected to statistical calculations which were performed using IBM SPSS (Statistical Package for Social Sciences) version 21 tool.

3. Result and Discussions

Table 2. Volatile Organic Compounds (VOCs) in Ambient Air from Stations 1, 2 and 3 during the Raining and Dry Seasons

	Stations	VOC (μg/m^3) Raining Season	VOC (μg/m^3) Dry Season
	1	1471^c±138	19950^a±2949
	2	700^c±141	14817^b±2053
	3	1086c^c±121	15283^b±1212
EPA Standard		-	102.1
National Standard		-	160
Detection Limit		1	0.1

Values are means ± standard deviation of six replications.
Mean values bearing different superscripts in the same column differ significantly ($p<0.05$).
Key:
VOC = Volatile Organic Compounds
Station 1 = Makoba
Station 2 = Elekahia
Station 3 = Rivers |State University

Table 3. Volatile Organic Components (VOCs) in Street Vended Foods during the Raining Season

SAMPLES	Benzene (ng/ul)	Toulene (ng/ul)	Ethyle Bz (ng/ul)	Xylene (ng/ul)
RP1	0	0	0	0
RP2	0	0	0	0
RP3	0	0	0	0
RF1	0	0	0	0
RF2	0	0	0	0
RF3	0	0	0	0
RY1	0	0	0	0
RY2	0	0	0	0
RY3	0	0	0	0
SY1	0	0	0	0
SY2	0	0	0	0
SY3	0	0	0	0
MP1	0	0	0	0
MP2	0	0	0	0
MP3	0	0	0	0
DN1	0	0	0	0
DN2	0	0	0	0
DN3	0	0	0	0
PAPER1	0	0	0	0
PAPER2	0	0	0	0
PAPER3	0	0	0	0

Values are means ± standard deviation of duplicate samples
Mean values bearing different superscripts in the same column differ significantly ($p<0.05$).
Key:
RP1 = roasted plantain from Makoba,Port-Harcourt, RP2 = roasted plantain from Elekahia, Port Harcourt, RP3 = roasted plantain from Rivers State University, Port Harcourt, RF1 = roasted fish Makoba, Port-Harcourt, RF2 = roasted fish from Elekahia, Port Harcourt, RF3 = roasted fish from Rivers State University, Port Harcourt, RY1 = roasted yam from Makoba,Port-Harcourt, RY2 = roasted yam from Elekahia, Port Harcourt, RY3 = roasted yam from Rivers State University, Port Harcourt, SY1 = suya from Makoba, Port-Harcourt, SY2 = suya from Elekahia, Port Harcourt, SY3 = suya from Rivers State University, Port Harcourt, MP1 = meat pie from Makoba,Port-Harcourt, MP2 = meat pie from Elekahia, Port Harcourt, DN1 = dough nut Makoba, Port-Harcourt, DN2 = dough nut from Elekahia, Port Harcourt, DN3 = dough nut from Rivers State University, Port Harcourt

Table 4. Volatile Organic Components (VOCs) in Vended Street Foods during the Dry Season

SAMPLES	Benzene (ng/ul)	Toulene (ng/ul)	Ethyle Bz (ng/ul)	Xylene (ng/ul)
RP1	0	0	0	0
RP2	0	0	0	0
RP3	0	0	0	0
RF1	0	0	0	0
RF2	0	0	0	0
RF3	0	0	0	0
RY1	0	0	0	0
RY2	0	0	0	0
RY3	0	0	0	0
SY1	0	0	0	0
SY2	0	0	0	0
SY3	0	0	0	0
MP1	0	0	0	0
MP2	0	0	0	0
MP3	0	0	0	0
DN1	0	0	2.0E-06	0
DN2	0	0	0	0
DN3	0	0	2.3E-06	0
PAPER1	0	0	0	0
PAPER2	0	0	0	0
PAPER3	0	0	0	0

Values are means ± standard deviation of duplicate samples
Mean values bearing different superscripts in the same column differ significantly ($p<0.05$).
Key
RP1 = roasted plantain Makoba,Port-Harcourt, RP2 = roasted plantain from Elekahia, Port Harcourt
RP3 = roasted plantain from Rivers State University, Port Harcourt, RF1 = roasted fish from Makoba,Port-Harcourt
RF2 = roasted fish from Elekahia, Port Harcourt, RF3 = roasted fish from Rivers State University, Port Harcourt
RY1 = roasted yam from Makoba,Port-Harcourt, RY2 = roasted yam from Elekahia, Port Harcourt
RY3 = roasted yam from Rivers State University, Port Harcourt
SY1 = suya from Makoba,Port-Harcourt, SY2 = suya from Elekahia, Port Harcourt
SY3 = suya from Rivers State University, Port Harcourt
MP1 = meat pie from Makoba,Port-Harcourt, MP2 = meat pie from Elekahia, Port Harcourt
MP3 = meat pie from Rivers State University, Port Harcourt
DN1 = doughnut from Makoba,Port-Harcourt, DN2 = doughnut from Elekahia, Port Harcourt
DN3 = doughnut from Rivers State University, Port Harcourt.

This research was carried out to investigate the food safety implications of the presence of VOCs in the environment and ready-to-eat vended foods during wet and dry seasons in parts of Port Harcourt City.

3.1. Seasonal variations of Volatile Organic compound in Ambient Air from Stations 1, 2 and 3 during the Raining and Dry Seasons

Table 2 showed that VOCs observed at all the stations and seasons were above the Nation standard limit of 160 μg/m^3 and detectable limit of 0.1. The highest values ranged from 14817- 19950 μg/m^{3}at Elekahia and Makoba respectively during the dry season. Also, during the raining season the highest values was recorded at Makoba 1471 μg/m^3 and lowest at Elekahia 700 μg/m^3 [7,19]. VOCs are emitted by a wide array of products numbering in the thousands; organic chemicals are widely used as ingredients in household products, Paints, varnishes wax, all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing and hobby products.

Fuels and some automotive products are made up of organic chemicals. All of these products can release organic compounds while you are using them, and, to some degree, when they are stored. In urban and industrial areas, many hydrocarbons, including VOCs, are emitted from anthropogenic sources, such as transportation, fossil fuel-burning power plants, chemical plants, petroleum refineries, certain construction activities, solid waste disposal and slash burning [20], In addition to the anthropogenic sources, many VOCs are produced naturally by vegetation. In a similar study carried out in Bangkok, by Japan International Cooperation Agency (JICA) and Pollution Control Department (PCD) [21] it was reported that Annual average concentration of nine VOC snamelybenzene, 1,3 butadiene, chloroform, dichloromethane, 1,2-dichloroethane, 1,2-dichloropropane, tetrachloroethylene, trichloroethylene, and vinyl chloride were compared with Thai annual ambient standard. It was 1, 3-butadiene that exceeded ambient air quality standard in some areas in Maptaphut and Bangkok. High concentrations of these compounds were expected not only emission from industry but also emission from mobile source particularly in Bangkok area. Chronic exposure of VOCs may affect other sensitive body tissues, like the bone marrow, as evidenced in the IARC monograph 109 IARC, [22], where carcinogenicity by outdoor air pollution was declared. This causes leukemia and central nervous system cancer in children exposed to benzene via automobile exhaust smoke or as a result of living in petrochemical areas or because their parents were exposed to gasoline or $PM_{2.5}$. Mother exposure during pregnancy has escaped epidemiological studies establishing a relationship with childhood leukemia, and it would be advisable to consider this aspect, because it has been determined that childhood leukemia appearing in the early years of life may have originated during embryo development [23].

Some VOCs that are identified as toxic air pollutants may have caused long-term health impacts on the population living in contaminated areas. Annual concentrations of 1, 3-butadiene were found higher than their annual standards in some areas in Maptaphut and Bangkok. All of the sampling sites in Bangkok area had benzene annual average concentration exceeded annual standard. It was expected that high concentration was attributed from both near source and mobile sources near the sampling site since these 2 compounds were well recognized as pollutants, not only emitted from industry but also emitted from vehicle. This assumption was proven by high concentrations of benzene and 1,3-butadiene in the roadside monitoring stations in Bangkok comparing with other monitor site categories concentrations of VOCs were greatly affected by local emission source nearby sampling location. For example, one of the sampling site in Bangkok was located close to the degreasing facility resulted to existing of dichloromethane in that area, while concentrations of this compound were found relatively low in Maptaphut area, [21].

This study recorded high values of VOCs around the three locations during both seasons, thus posing a health concerns for humans resident within the area of study.

VOC value was highest (19950.0 µg/m^3) at station 1 during the dry season and as low as (1471.4 µg/m^3) during the raining season at the same station. However, both values recorded were above the national standard as well as the EPA standards of 102.1 µg/m^3 . The toxic gas VOCs was present in the ambient air around the three study stations with mean concentrations for both seasons greater than the FMEnv national standard during the dry season, with the tendency of posing health implications to receptors. It is evident that a large part of BTEX emissions into the atmosphere originate from biogenic processes, a considerable amount comes from anthropogenic sources that could be regulated more efficiently [24], In the European Union and the United States, VOC emissions have been reduced by regulating industrial processes, improving vehicle engines and reducing gasoline, solvents, paints and other sources. This study, therefore suggest that the Nigerian government to urgently look in this direction of VOCs reduction through legislative framework.

3.2. Volatile Organic Components (VOCs) in Street Vended Foods during the Raining Season

Volatile organic component (Benzene, Toluene, Ethyl Benzene and Xylene) were not detected in the street vended food samples during the raining season. This study showed that though VOCs were present in the environment during raining season, but were not detected in the food samples, the consumption of these ready -to-eat foods may not be implicated for VOCs contaminations. However, the presence of VOCs in the environment is in agreement with the study of ASTDR [25] that detected BTEX in a particular environment and concluded that the presence of BTEX in the investigated area is a risk factor for the inhabitants. This is of public health concern due to the pathways of these contaminants not only through ingestion, but by inhalation, and contact [1]. Benzene is a high-priority urban air pollutant; it is a well-known human carcinogen for all routes of exposure. According to toxicological studies, Environmental Protection Agency (USEPA, [7] has classified benzene as a Group A, human carcinogen, and International Agency for Research on Cancer (IARC) considers benzene as confirmed and probable carcinogen as well as mutagenic [25]. Toluene is less toxic and causes drowsiness, and impaired coordination. Xylene exhibits neurological effects and can cause irritation of the skin, eyes, nose, and throat, difficulty in breathing. From the current study, it is safe to suggest that the absence of BTEX in street vended food is an indicator that street vended food across these locations is safe for consumption during the raining season, if they do not contain any contaminants or pollutants.

3.3. Volatile Organic Components (VOCs) in Street Vended Foods during the Dry Season

Table 4 shows the presence of volatile organic compounds in Street Vended Food (SVF). Ethyl Benzene was present in doughnut from the Rivers State University and Makoba during the dry season at a level of 2.0 x 10^6 ng/ul and 2.3x10^6 ng/ul respectively**.** Benzene, toluene and xylene were not detected in other food samples. It is likely that the dry season favor's the retention of Ethyl Benzene on doughnut. However, Ethyl Benzene was not detected in doughnuts hawked around Elekahia. Some VOCs can pose potential risks to human health. For example, benzene and 1, 3-butadiene have been linked with increases in diseases such as leukemia; formaldehyde is classified as a potential nasal carcinogen agent; while the polycyclic aromatic hydrocarbons are considered as potential lung cancer inducing agents [11,12]. The findings in the present study corroborates the work of Singla et al., *[26]* that besides aliphatic hydrocarbons, the aromatic hydrocarbons, especially benzene, toluene, ethylbenzene, m, p-xylene and o-xylene (BTEX) represents another class of common urban pollutants related to traffic emissions. Aromatic hydrocarbons represent a significant fraction of the VOCs emitted in urban environment by road traffic, especially by the use of unleaded gasoline which is rich in aromatic hydrocarbons (up to 45%).

BTEX are cited to be the most abundant among the aromatic hydrocarbons and are of great concern because of their role in tropospheric chemistry and because of the human health negative impact. National Academic Press (NAP) [27] reported that Benzene, the major representative of this class, is known under occupational circumstances to be capable of producing mutations and is considered by many as a carcinogen because of its likelihood of producing leukemia, as well as interfering with bone marrow function. The highest atmospheric concentration of benzene is one five-thousandth the concentration thought likely to damage health under occupational circumstances; for this reason, the present concentrations may be considered harmful. Increases in these concentrations, however, should not be permitted without careful evaluation of their possible health implications. Vapor-Phase Organic Pollutants: Volatile Hydrocarbons and Oxidation Products [27], The detection of the presence of Ethyl Benzene in the food sample collected at Makoba and Rivers State University as wells as total VOCS found in these environment is of public health concerns particularly for children and elderly leaving within these environment. Several authors had quantified BTEX metabolites in children's urine samples, and each one quantified different metabolites. Accordingly, Flores-Ramirez et al., [28] found a high level of exposure to benzene in children of a remote rural community crossed by a river polluted with industrial waste in a continental tropical zone. This finding was in collaboration with Pelallo et al. [29], Lij et al, [30] that reported the highest levels of child exposure to benzene and toluene in three communities surrounded by petrochemical facilities in a tropical coastal region. In another account, Olmos et al. [[31]] reported high levels of exposure to benzene in the industrial area of a large capital city like Buenos Aires.

The same results repeat in similar studies on children living in polluted industrial areas in Korea, [32,33,43], and Mexico. Children living close to industrial settings show higher levels of metabolites of benzene, which has been the most studied VOC as it is carcinogenic. That the highest levels of benzene exposure were found in tropical areas could be due to the high temperatures, which allow the widest distribution of contaminants into the air as evident in the presence of Ethyl Benzene in food sample during the dry season. This is in collaboration with work of Lizette Menchaca-Torre et al [34], VOC concentrations exhibited a marked diurnal behavior with higher concentrations during the morning intervals. Solar radiation peaked during the noon interval, allowing for greater secondary pollutant production. VOCs reached their lowest levels in the 14:00-18:00 time interval. Correlation analysis found evidence of mobile sources, fugitive fuel emissions, and the use of solvents as possible sources of the majority of the compounds.

3.4. Effects of Season and Location on the Volatile Organic Components (VOCs) in Street Vended Foods

The effect of interaction between season and location on VOCs in Ready-to-eat street vended foods was significant ($P<0.05$). Ethyl Benzene was present only in doughnut from station 3 (Rivers State University) and Station 1 , Makoba during the dry season at a level of $2.3x10^6$ ng/ul and of 2.0 x 10^6 ng/ul . The values of Ethyl Benzene in the street vended foods appears to be high and may have health implications. The level of aliphatic and aromatic hydrocarbons was higher in the urban area of Rivers State University and in the rural area of Makoba, with exception that at Elekahia which is an urban area nothing was detected. This result agrees with the findings of Watson *et al.*, [35]. Reported that the presence of these pollutants in urban environments is often dominated by vehicular emissions involving fuel distribution, evaporation and automobile exhaust. The aliphatic hydrocarbons and some of the aromatic hydrocarbons (benzene, ethylbenzene, toluene, and xylenes) are characteristic products of internal combustion engines and can be emitted from the evaporation of gasoline, diesel and liquefied petroleum gas (LPG) [36] and this may be applicable to the Rivers State University gate, where various vehicular movement involving the movement of students to the different parts of the school is a common daily activities. Makoba area of Port Harcourt is known for the many industrial activities involving heavy duty vehicles used in the transportation of refined petroleum products to different parts of the state. The presence of Ethyl benzene have been implicated in some health conditions. In a study by Roba *et al.*, [37], it was discovered that Benzene (4.26 - 7.02 µg/m3) and toluene (11.48 - 14.90 µg/m3) were the most abundant BTEX detected in the urban area. The presence of benzene and toluene is related to gasoline combustion which is known to contain high proportion of these compounds. Further, benzene and toluene have a longer life time (12.5 and 2 days respectively) and are known to be relatively stable and do not dissipate into the environment immediately after release [26]. Benzene to Toluene (B/T) ratio has been commonly used as an indicator of traffic emissions. If the B/T ratio is 0.5 [38] or it ranges between 0.33 and 0.67 [39], it indicates that the traffic is the dominant source of VOCs emission and Rivers State University may be implicated for the high level of traffic at the University gate where this study was carried out. Batter Man et al., [40], & Sosa et al., [41] reported that High BTEX concentrations have been found in areas with intensive industrial activity, but they also reach high levels in large cities, mostly owing to vehicular traffic problems. Furthermore, there may be additional exposure owing to household products, like disinfectants, aerosols, varnishes, printing inks [42], as well as cigarette smoke, which turns them into ubiquitous pollutants.

According to Oyet et al [15] who reported in a similar study on poly aromatic hydrocarbon (PAHs) that at station 1(Makoba) the lower molecular weight (LMW) PAHs, those with 2-3 aromatic rings were not detected in roasted plantain and Yam during the wet and dry season. The non-detection of these PAHs may be due to the seasonal effect of rainy season and the cold precipitation of the dry season common at Makobar. Rain may have acted as cleaning agents to reduce the deposits and concentrations of the PAHs on food samples. The findings validates the work Skupinska *et al.* [44] that once PAHs is emitted to the atmosphere, weight influences the fate of the gaseous PAH mixtures. Heavier PAHs (more than four rings) tend to adsorbed to particulate matter, while lighter PAHs (less than four rings) tend to remain gaseous until removed via precipitation

4. Conclusion

The toxic emission VOCs or BTEX was present in the ambient air around the three study stations with mean concentrations for both seasons greater than the FMEnv. Regulatory standard (160 µg/m^3) during dry and wet seasons, with the tendency of posing health implications to human and food receptors. The highest value were detected in Makoba and Rivers State University during the dry season respectively. Volatile organic component (Benzene, Toluene, Ethyl Benzene and Xylene) were not detected in the street vended food samples during the raining season. However, during the dry season, Ethyl Benzene was detected in DN1 and DN3.The effect of interaction between season and location on VOCs in street vended foods was significant ($P<0.05$). Recommdation: Further studies to be conducted to investigate and monitor air quality around these communities that co-habit with oil and gas activities and make these finding known to the inhabitants, to enable them appreciate the need for adoption of controlled strategies and barriers as may be made know through community awareness. This will help to save the lives of the younger ones and elderly. Also, the toxicity of these Ready -to- eat food associated VOCs in the environment as well as engagement in further studies to establish the pathways of these environmental pollutants on the food chain. This study, therefore suggest that the Nigerian Federal Government to urgently look in the direction of VOCs reduction through legislative framework.

References

[1] Lesa A. Thompson and Wageh S. Darwish (2019). Environmental Chemical Contaminants in Food: Review of a Global Problem. Hindawi Journal of Toxicology Volume 2019, Article ID 2345283, 14 pages.

[2] Sharmila Rane, (2011). Street Vended Food in Developing World: Hazard Analyses*. Indian J Microbiol*. 51(1):100-106.

[3] FAO (1989) Street foods. A summary of FAO studies and other activities relating to street foods. FAO, Rome.

[4] Ilaria Proietti, Chiara Frazzoli., &Alberto Mantovani (2014). Identification and Management of toxicological hazards of Street foods in developing Countries. *PUBMED. Food Chem Toxicol.* 63:143-152.

[5] HRIA (Health Resources in Action). (2013). *Defining healthy communities*. Boston, MA: HRIA. http://hria.org/uploads/catalogerfiles/defining healthycommunities/defining_healthy_communities_1113_final_report.pdf (accessed June 14, 2017).

[6] EGASPIN (2018). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria. Directorate of Petroleum Resources. Ministry of Petroleum.

[7] United States Environmental Protection Agency. Integrated Risk Information System on Benzene. National Center for Environmental Assessment, Office of Research and Development, Washington, D.C.; 2012. https://www.epa.gov/sites/production/files/2016-09/documents/benzene.pdf. Accessed May 2020.

[8] Anjali-Srivastava& Dipanjali Mazumdar (2011). Monitoring and Reporting VOCs in Ambient Air, Air Quality Monitoring, Assessment and Management, Dr. Nicolas Mazzeo (Ed.), ISBN: 978-953-307-317-0, InTech, Available from: http://www.intechopen.com/books/air-quality-monitoring-assessment- and management/ monitoring-and-reporting-vocs-in-ambient-air.

[9] Guenther, A., Hewitt, C. N., Erickson, D., Fall, R., Geron, C., Graedel, T., Harley, P., Klinger, L., Lerdau, M., Mckay, W. A., Pierce, T., Scholes, B., Steinbrecher, R., Tallamraju, R., Taylor, J., & Zimmerman. (1995). Global-Model of Natural Volatile Organic- Compound Emissions, *Journal Geophys. Res.- Atmos.*, *100 (5):* 8873-8892.

[10] Talapatra, A., & Srivastava, A. (2011). Ambient air Non- Methane Volatile Organic Compound (NMVOC) study initiatives in India-A Review, *Journal of Environmental Protection*, 2**:** 21-36.

[11] Goldstein, A.H., & Galbally, I.E., (2007). Known and Unexplored Organic Constituents in the Earth's Atmosphere, *Environmental Science & Technology*, 41, 1514-1521.

[12] Sahu, L.K., (2012). Volatile organic compounds and their measurements in the troposph andere, *Current Science,* 102, 1645-1649.

[13] Huang, C., Chen, C.H., Li, L., Cheng, Z., Wang, H.L., Huang, H.Y., Streets, D.G., Wang, Y.J., Zhang, G.F., Chen, Y.R. (2011). Emission inventory of anthropogenic air pollutants and VOC species in the Yangtze River Delta region, China, *Atmospheric Chemistry and Physics*, 11, 4105-4120.

[14] Demographia (2015). *Demographia World Urban Areas (Built Up Urban Areas or World Agglomerations), 11th edition*. Retrieved from https://www.urbangateway.org/es/system/files/documents/urbangateway/db-worldua.pdf.

[15] Oyet, G.I, Achinewhu, S.C., Kiin-Kabari,D.B, & Akusu, M.O (2020). Impact of Wet and Dry Seasons on the Distribution of Polycyclic Aromatic Hydrocarbons in Selected Vended Street Foods in Parts of Port Harcourt Metropolis. *European Journal of Nutrition & Food Safety.* 12(1): 16-29, 2020.

[16] Demeestere, K.; Dewulf, J.; Witte, B. D.; Lange hove, H. V. (2007) Sample preparation for the analysis of volatile organic compounds in air and water matrices. *Journal of Chromatography A,* Vol. 1153, pp. 130-144.

[17] WHO, (1988). International Operator's Handbook for the Measurement of Background Atmospheric Pollution No. 491E.

[18] APHA (American Public Health Association) (1998). Standard methods for the examination of water and wastewater. 16th Edition, Washington D.C.

[19] FMEnv (1991). Federal Environmental Protection Agency 1991. National Interim Guidelines and Standards for Industrial Effluent, Gases emission and Hazard s waste management in Nigerian.

[20] Davis, C.S., & Otson, R. (1996). Estimation of emissions of volatile organic compounds (VOCs) from Canadian residences.

[21] Japan International Cooperation Agency (JICA) & Pollution Control Department (PCD) and Department of Environmental Quality Promotion. (2008). *Project on the development of Environmental and Emission Standards of VOCs. - VOCs Ambient Air Monitoring Draft Report. Ministry of Natural Resources and Environment, Bangkok. Thailand*

[22] International Agency for Research on Cancer. Outdoor air pollution. IARC monographs on the evaluation of carcinogenic risks to humans. 2016; 109. IARC-WHO, Lyon, France.

http://monographs.iarc.fr/ENG/Monographs/vol109/index.php. Accessed May 2020.

[23] Belson M, Kingsley B and Holmes A. Risk factors for acute leukemia in children: A review. Environ Health Perspectives. 2007; 15: 138-45.

[24] Montero-Montoya, R., López-Vargas, R. and Arellano-Aguilar, O., (2018). Volatile Organic Compounds in Air: Sources, Distribution, Exposure and Associated Illnesses in Children. *Annals of Global Health*, 84(2), pp.225-238.

[25] ATSDR (Agency for Toxic Substances and Disease Registry (2000). Toxicological Profile for Toluene, Agency for Toxic Substances and Disease Registry, Atlanta, USA, on line at: http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=161&ti.

[26] Singla, V., Pachauri, T., Satsangi, A., Kumari, K.M., &Lakhani, A. (2012). Comparison of BTX profiles and their mutagenicity assessment at two sites of Agra, *India, Scientific World Journal, ID 272853.*

[27] National Academies Press (1976). Vapor-Phase Organic Pollutants: Volatile Hydrocarbons and Oxidation Products. Copyright National Academy of Sciences. All rights reserved, National Academy of Sciences Washington, D.C. 1976.

[28] Flores-Ramírez R, Pérez-Vázquez FJ, Cilia-López VG, et al. Assessment of exposure to mixture pollutants in Mexican indigenous children. Environ Sci Pollut Res Int. 2016; 23: 8577-88.

[29] Pelallo-Martínez NA, Batres-Esquivel L, Carrizales-Yáñex L and Díaz-Barriga F. Genotoxic and hematological effects in children exposed to a chemical mixture in a petrochemical área in México. Arch Environ Contam Toxicol. 2014; 67: 1–8.

[30] Li J, Lu S, Liu G, et al. Co-exposure to polycyclic aromatic hydrocarbons, benzene and toluene and their dose-effects on oxidative stress damage in kindergarten-aged children in Guangzhou, China. Science of the Total Environ. 2015; 524-25: 74-80.

[31] Olmos V, Lenzken SC, López CM and Villaamil EC. High-performance liquid chromatography method for urinary Trans, trans-muconic acid. Application to environmental exposure to benzene. J Anal Toxicol. 2006; 30: 258-61.

[32] Fang MZ, Shin MK, Park KW, Kim YS, Lee JW and Cho MH. Analysis of urinary 5-phenylmercapturic acid and Trans, trans-muconic acid as exposure biomarkers of benzene in petrochemical and industrial areas of Korea. *Scand J Work Environ Health*. 2000; 26: 62-6.

[33] Perez-Maldonado IN, Ochoa-Martinez AC, Orta-Garcia ST, Ruiz-Vera T and Varela-Silva JA. Concentrations of Environmental Chemicals in Urine and Blood Samples of Children from San Luis Potosí, Mexico. Bull Environ Contam Toxicol. 2017; 99: 258-63.

[34] Lizette Menchaca-Torre, RoberoMercado- Hernandez and AlbertoMandozaa- Dominguez. (2015). Diurnal and seasonal variation of volatile organic compounds in the atmosphere of Monterrey, Mexico. Atmospheric Pollution Research. Volume 6, Issue 6, November 2015, Pages 1073-1081.

[35] Watson John G., Judith Chow C., Arriaga, J.LReyes Enoc., Sanchez Gabriela, Vega Elizabeth., Egami, R.T., and Mugica-Alvarez, Violeta (2001).Volatile organic compounds emissions from gasoline and diesel powered vehicle. Atmosfere 14: 29-37.

[36] Barletta, B., Meinardi, S., Simpson, I.J., Khwaja, H.A., Blake, D.R., & Rowland, F.S., (2002). Mixing ratios of volatile organic compounds (VOCs) in the atmosphere of Karachi, Pakistan, *Atmospheric Environment,* 36: 3429-3443.

[37] Roba Carmen, Horaţiu Ştefãnie, Zoltán Török1, Melinda Kovacs, Cristina Roşu, & Alexandru Ozunu, (2014). Determination of volatile organic compounds and particulate matter levels in an urban area from Romania. *Environmental Engineering and Management Journal*,13 *(9)* 2261-2268.

[38] Scheff, P.A., & Wadden, R.A., (1993). Receptor modeling of volatile organic compounds. I: Emission inventory and validation, *Environmental Science and Technology*, 27, 617-625.

[39] Miller L., Xu X.H., Wheeler A., Atari, D.O., Grgicak-Mannion, A., &Luginaah, I. (2011). Spatial Variability and Application of Ratios between BTEX in Two Canadian Cities, *The Scientific World Journal,* 11: 2536-2549.

[40] Batterman S, Su F-C, Li S, Mukherjee B and Jia C. Personal Exposure to Mixtures of Volatile Organic Compounds: Modeling and Further Analysis of the RIOPA Data. Resp Rep Health Eff Inst. 2014; 181: 3-63.

[41] Sosa RE, Bravo HA, Mugica VA, Sanchez PA, Bueno EL and Krupa S. Levels and source apportionment of volatile organic compounds in southwestern area of Mexico City. Environ Pollut. 2009; 157: 1038-44.

[42] Gresner P, Stepknik M, Krol MB, et al. Dysregulation of markers of oxidative stress and DNA damage among nail technicians despite low exposure to volatile organic compounds. Scand J Work Environ Health. 2015; 41: 579-593.

[43] Tuakuila J, Kabamba M, Mata H and Mbuyi F. Tentative reference values for environmental pollutants in blood or urine from the children of Kinshasa. Chemosphere. 2015; 139: 326-33.

[44] Skupinska, K. Misiewicz, I. Kasprzycka-Guttman, T. (2004). Polycyclic aromatic hydrocarbons: physiochemical properties, environmental appearance and impact on living organisms. *Acta Pol Pharm*, 61(3): 233-240.