Air quality at Artisanal Crude Oil Refinery Sites in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria

Abstract

Artisanal crude oil refining is an illegal operation thriving in the oil rich Niger Delta region of Nigeria, and their activities are known to cause serious air pollution, evident by incidences of black soot pollution in many parts of this region. This study aimed to ascertain the air quality around artisanal crude oil refinery sites situated in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria. Air quality assessment was carried out using air quality sensor for physicochemical parameter and settle plate exposure for microbial parameters, monitored for both dry and wet season. During the wet season, SOx, NOx, VOC, CH_4, CO, CO_2,O_3, NH_3, H_2S, PM 1, PM 2.5, PM 7, PM10, TSP, Noise, Wind speed, Air temperature, Relative humidity concentration ranged from 0-0.05 ppm, 0.04 - 0.07 ppm, 1004.00 - 1320.00 ppm, 34.33 - 39.67 ppm, 1.33 - 3.00 ppm, 765.00-1556.67 ppm, 0.2 to 0.3 ppm, 0.05 to 0.10 ppm, 0.13 to 0.20 ppm, 15.73 - 0 21.50 µg/m^3, 33.53-34.17 µg/m^3, 55.47 - 55.93 µg/m^3, 64.30 - 67.50 µg/m^3, 49.60 - 76.97 µg/m^3, 45.63– 48.37dB, 1.13 -1.23 M/S, 28.30 - 29.73^{o}C and 63.13 - 69.23 % respectively. During the dry season, SOx, NOx, VOC, CH_4, CO, $CO_{2,}$ O_3, NH_3, H_2S, PM 1, PM 2.5, PM 7, PM10, TSP, Noise, Wind speed, Air temperature, Relative humidity concentration ranged from 0.08-0.53 ppm, 0.12 - 0.19 ppm, 1027.33 - 1750.33 ppm, 21.00 - 50.33 ppm, 1.33 – 2.67 ppm, 1226.67-1551540.00 ppm, 0.09 to 0.55 ppm, 0.04 to 0.09 ppm, 0.04 to 0.63 ppm, 26.47 - 33.97 µg/m^3, 39.60-51.23 µg/m^3, 57.90 - 84.27 µg/m^3, 89.13 - 100.17 µg/m^3, 128.83 – 170.30 µg/m^3, 49.17– 56.73dB, 0.15 -1.97 M/S, 29.07 - 32.57^{o}C and 66.67 - 71.87 % respectively. Results revealed statically significant differences ($p<0.05$) in air parameters per season (dry and wet) and between impacted sites and control, as regards NOx, VOC, CO_2, O_3, PM 1, PM 2.5, PM 4, PM 7, PM 10, TSP and noise levels. During the dry season, THBC ranged from 4.4-4.8 log CFU/m^3 and TFC ranged from 4.4-4.8 log CFU/m^3. During the wet season THBC ranged from 4.9-5.2 log CFU/m^3 and TFC ranged from 2.5-4.6 log CFU/m^3.

Results revealed no statically significant differences ($p<0.05$) in microbial count per season (dry and wet) as well as between polluted site and control. The bacterial isolates were identified as belonging to five genera: Bacillus, Micrococcus, Pseudomonas, Staphylococcus and Escherichia, while the fungal isolates belong to three genera: Fusarium, Aspergillus and Penicillium. The excessive concentrations of NOx, SOx, and presence of allergenic and pathogenic microorganisms could pose danger to public health.

Keywords: Air quality, artisanal crude oil refinery, exposure, public health

1. INTRODUCTION

Nigeria is a leading exporter of crude oil in Africa with little refining capacity [1]. The availability of crude oil stolen from networks of pipelines crisscrossing the Niger Delta, has led to the boom in artisanal crude oil refineries both as a means to provide cheap fuel and as source of economic empowerment to the indigenous people who have been agitating for resource control [2-4].

In the past, the danger of polluting air, water, soil and biota by artisanal crude oil refineries operators in the Niger Delta was not fully recognized as a grave problem, but now there is no doubt that it is a matter of great concern owing to reports of its correlation with respiratory illnesses, cancer, heart diseases, birth related anomalies among other mortalities [5]. In November 2016, most of the urban parts of Rivers State became enveloped by a thick haze of "strange black soot" from illegal refineries, to exacerbate the existent problem of gas flares from oil fields and petrochemical refineries [6,7]. Soot from hydrocarbon combustion is now a common vegetation, water, soil, and air pollution in Niger Delta region of Nigeria [8,9].

Artisanal crude oil refining soot, which is a mass of impure carbon particles resulting from the incomplete combustion of hydrocarbons [8], as well as other pollutant of various species, including carbon dioxide, carbon monoxide, hydrogen sulphide, various gaseous hydrocarbons including methane, oxides of nitrogen and sulphur, particulates, ash and heavy metals [4,8,10]. These pollutants alter the physicochemical and the microbiological quality of air. Soot can serve to transport inhalable microorganisms which can be allergenic and pathogenic, and therefore create a potential danger on public health [9].

Emphasis on the study of the effect of artisanal crude oil refining on air quality has been on the physicochemical parameters alone. But because microorganisms can sorb on to soot, it is important to look at both the physicochemical and microbiology parameters around the artisanal crude oil refinery sites. Thus, this study aimed to determine the impact of artisanal refinery operations on the physicochemical and microbiology quality of air in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study area, Igia-Ama, is part of the Kalabari speaking tribe of the Tombia Kingdom of Rivers State, Nigeria. This area lies within the geographical coordinates 4^0 53’ 12.7’’ North, 7^0 07’ 30.6’’ East (Figure 1). The people of this kingdom are approximately 15,000 in population and inhabit the Degema Local Government Area of the State. The oil rich region is accessible through its waterways. Aside the presence of oil and gas infrastructure, the people engage in fishing and arable agriculture.

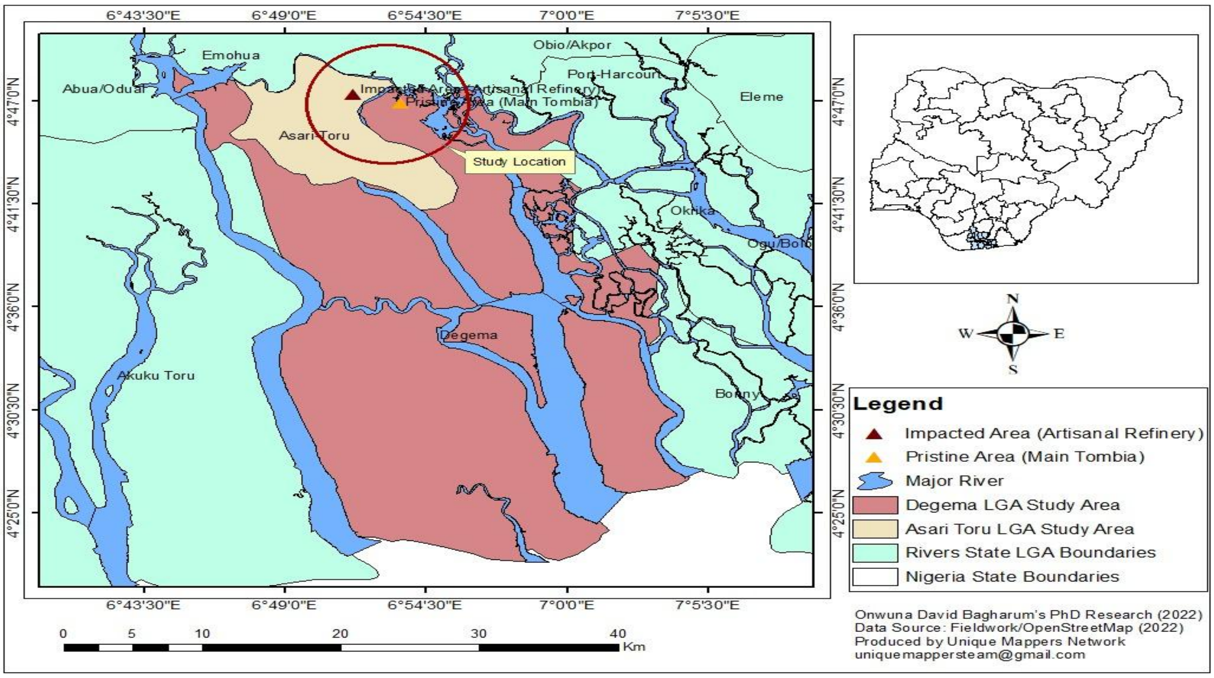

Figure 1: Sampling location in Rivers State

2.2 Air Sampling

Air sampling was done three (3) times a day; morning, noon and evening for three (3) consecutive periods during dry season and same was carried out during wet season as well. One (1) control point located far from the impacted area on the leeward side of wind direction, was used. Installed gas device (Aeroqual) was used to determine the concentrations of NOx, VOC, CH_4, CO, CO_2, O_3, PM 1, PM 2.5, PM 4, PM 7, PM 10, TSP, noise, SOx, NH_3, H_2S, wind speed, air temperature (ambient), wind direction and relative humidity. The settle plate method described by Mbakwem-Aniebo et al. [11] was used for the isolation of microorganism in the air.

2.3 Enumeration and Characterization of of Isolates

Enumeration of isolates was done using the Omeliansky's formula ($N=5a \times 10^4/bt$) with counts expressed in CFU/m^3.

Bacterial isolates were identified based on their morphological colony characteristics, Gram reaction and biochemical tests (indole test, catalase test, citrate test, motility test, urease test, starch hydrolase test, and sugar fermentation) as outlined by Cheesbrough [12]. Bergey's manual of systematic bacteriology [13] was used as reference for bacteria identification. Fungal isolates were identified based on their microscopic and macroscopic characteristics with reference to descriptions by Salvamani and Nawawi [14].

3. RESULTS

3.1 Physicochemical and Meteorological Parameter of Air

During the wet season, SOx, NOx, VOC, CH_4, CO, CO_2,O_3, NH_3, H_2S, PM 1, PM 2.5, PM 7, PM10, TSP, Noise, Wind speed, Air temperature, Relative humidity concentration ranged from 0-0.05 ppm, 0.04 - 0.07 ppm, 1004.00 - 1320.00 ppm, 34.33 - 39.67 ppm, 1.33 - 3.00 ppm, 765.00-1556.67 ppm, 0.2 to 0.3 ppm, 0.05 to 0.10 ppm, 0.13 to 0.20 ppm, 15.73 - 0 21.50 µg/m^3, 33.53-34.17 µg/m^3, 55.47 - 55.93 µg/m^3, 64.30 - 67.50 µg/m^3, 49.60 - 76.97 µg/m^3, 45.63– 48.37dB, 1.13 -1.23 M/S, 28.30 - 29.73^{o}C and 63.13 - 69.23 respectively (Table 1).

During the dry season, SOx, NOx, VOC, CH_4, CO, $CO_{2,}$ O_3, NH_3, H_2S, PM 1, PM 2.5, PM 7, PM10, TSP, Noise, Wind speed, Air temperature, Relative humidity concentration ranged from 0.08-0.53 ppm, 0.12 - 0.19 ppm, 1027.33 - 1750.33 ppm, 21.00 - 50.33 ppm, 1.33 – 2.67 ppm, 1226.67-1551540.00 ppm, 0.09 to 0.55 ppm, 0.04 to 0.09 ppm, 0.04 to 0.63 ppm, 26.47 - 33.97 µg/m^3, 39.60-51.23 µg/m^3, 57.90 - 84.27 µg/m^3, 89.13 - 100.17 µg/m^3, 128.83 – 170.30 µg/m^3, 49.17– 56.73dB, 0.15 -1.97 M/S, 29.07 - 32.57^{o}C and 66.67 - 71.87 respectively (Table 2).

Two-way analysis of variance results revealed statically significant difference ($p<0.05$) in concentrations of NOx, VOC, CH_4, CO, CO_2, O_3, PM 1, PM 2.5, PM 4, PM 7, PM 10, TSP and noise, between polluted and control samples. However, for SOx, NH_3, H_2S, wind speed, air temp (ambient) and relative humidity no statically significant difference ($p>0.05$) was observed. Also, results revealed statically significant differences ($p<0.05$) in air parameters per season (dry and wet) with regards to NOx, VOC, CO_2, O_3, PM 1, PM 2.5, PM 4, PM 7, PM 10, TSP and noise, while SOx, CH_4, CO,NH_3, H_2S, wind speed, air temperature and relative humidity were not significantly different ($p>0.05$).

Table 1: Air parameters (Wet season)

	Polluted sites						Control						
Parameter	**Morning**		**Afternoon**		**Evening**		**Morning**		**Afternoon**		**Evening**		
	Mean	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**FMEnv. Limit**
SOx(ppm)	0.05	0.01	0.03	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
NOx(ppm)	0.07	0.00	0.04	0.01	0.06	0.00	0.04	0.01	0.04	0.01	0.05	0.01	0.04-0.06
VOC(ppm)	1123.33	5.77	1004.00	19.70	1320.00	110.00	10.67	1.15	9.67	1.53	6.67	1.53	NS
CH_4(ppm)	37.67	2.52	34.33	4.04	39.67	1.53	8.00	2.00	4.33	1.53	5.67	1.15	NS
CO(ppm)	2.00	0.00	1.33	0.58	3.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	10
CO_2(ppm)	765.00	47.70	1003.33	185.83	1556.67	28.87	543.33	40.41	610.00	36.06	723.33	15.28	NS
O_3(ppm)	0.03	0.01	0.02	0.01	0.03	0.01	0.02	0.01	0.01	0.00	0.01	0.01	NS
NH_3(ppm)	0.10	0.00	0.10	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	NS
H_2S(ppm)	0.20	0.00	0.13	0.06	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NS
PM 1($\mu g/m^3$)	15.73	0.31	16.17	2.01	21.50	0.90	4.33	0.25	4.90	0.44	5.87	0.40	NS
PM 2.5($\mu g/m^3$)	33.53	0.51	34.17	1.63	33.53	0.51	8.13	0.21	9.40	0.75	10.43	0.12	NS
PM 4($\mu g/m^3$)	46.80	0.56	44.77	1.12	45.30	2.54	12.43	0.15	13.93	0.64	13.20	0.30	NS
PM 7($\mu g/m^3$)	55.93	1.75	56.93	0.32	55.47	0.81	17.90	0.36	19.50	0.90	19.83	0.49	NS
PM 10($\mu g/m^3$)	64.30	1.44	67.13	2.63	67.50	1.85	22.73	0.85	25.03	0.64	30.47	0.06	NS
TSP ($\mu g/m^3$)	76.97	4.65	49.60	26.42	76.73	2.93	54.80	4.56	58.07	0.58	56.43	1.00	250
Noise (dB)	45.63	0.70	45.87	0.60	48.37	1.03	43.97	0.40	53.40	2.76	53.80	0.69	90
Wind speed (m/s)	1.23	0.15	1.23	0.15	1.13	0.06	0.57	0.31	0.70	0.10	1.23	0.15	NS
Air Temp	29.57	0.06	29.73	0.42	28.30	0.26	29.93	0.06	30.10	0.10	32.33	0.06	NS

(Ambient) °C													
Relative Humidity (%)	68.73	0.06	63.13	1.91	69.23	0.31	63.80	0.00	64.03	1.19	70.67	0.40	NS
Wind Direction	NE	NE	NNE	NE	NE	NNE	NE	NE	NNE	NE	NE	NNE	NS

Table 2: Air parameters (Dry season)

	Polluted sites						Control site						
	Morning		**Afternoon**		**Evening**		**Morning**		**Afternoon**		**Evening**		
Parameter	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	**FMEnv. Limit**
SOx(ppm)	0.09	0.01	0.08	0.01	0.53	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.01
NOx(ppm)	0.12	0.00	0.14	0.01	0.19	0.01	0.06	0.02	0.10	0.01	0.08	0.01	0.04-0.06
VOC(ppm)	1027.33	158.31	1064.33	55.01	1750.33	25.89	535.00	5.57	721.67	10.07	928.67	47.06	NS
CH_4(ppm)	21.00	2.00	21.00	3.00	50.33	5.86	4.67	0.58	4.00	0.00	10.67	0.58	NS
CO(ppm)	1.33	0.58	2.67	1.15	2.67	1.53	0.00	0.00	0.00	0.00	0.00	0.00	10
CO_2(ppm)	1407.33	15.53	1540.00	70.00	1226.67	86.22	977.67	25.74	1153.33	51.32	1223.33	90.74	NS
O_3(ppm)	0.55	0.06	0.64	0.05	0.09	0.01	0.02	0.01	0.01	0.00	0.06	0.02	NS
NH_3(ppm)	0.04	0.03	0.09	0.01	0.60	0.10	0.00	0.00	0.00	0.00	0.00	0.00	NS
H_2S(ppm)	0.04	0.02	0.06	0.01	0.63	0.48	0.00	0.00	0.00	0.00	0.00	0.00	NS
PM 1(µg/m^3)	26.47	2.18	33.97	2.15	33.83	3.14	12.93	1.25	21.57	2.53	27.17	1.43	NS
PM 2.5(µg/m^3)	46.33	4.20	51.23	0.47	39.60	0.82	18.10	1.08	22.93	1.17	31.57	0.21	NS
PM 4 (µg/m^3)	79.53	11.11	84.27	2.41	57.90	1.83	26.77	1.22	32.33	0.47	39.93	0.35	NS
PM 7 (µg/m^3)	94.20	6.27	100.17	1.63	89.13	1.46	43.30	1.40	44.63	0.95	52.70	0.92	NS
PM 10 (µg/m^3)	108.33	5.70	116.53	3.49	127.53	5.35	75.97	2.41	85.47	2.63	81.23	1.53	NS

TSP (µg/m^3)	128.83	14.23	134.67	6.34	170.30	6.62	83.80	2.25	99.27	2.51	99.30	1.31	250
Noise (dB)	49.17	2.31	56.73	2.77	55.07	2.02	65.93	1.38	70.40	1.45	71.03	2.05	90
Wind speed (m/s)	1.23	0.32	1.97	0.15	0.63	0.15	0.90	0.10	2.43	0.06	2.17	0.21	NS
Air Temp (Ambient) ^{o}C	30.70	0.72	32.57	0.50	29.07	0.25	31.67	0.21	33.50	0.98	31.53	0.06	NS
Relative Humidity (%)	72.23	0.42	66.53	3.55	73.67	0.72	71.87	0.55	65.67	1.03	72.50	0.98	NS
Wind Direction	SE	SE	E	E	SE	SE	NE	NE	N	N	N	NE	NS

3.2 Bacterial and Fungal Counts in Air

Figure 2 shows THBC results for air at polluted site and control during the dry and wet seasons. During the dry season, THBC ranged from 4.4-4.8 log CFU/m^3 in polluted sites, with the highest count (4.8 log CFU/m^3) recorded in afternoon and least (4.4 log CFU/m^3) in the morning and evening. THBC ranged from 4.6-4.86 log CFU/m^{3}in the control site, with the highest count (4.8 log CFU/m^3) recorded in the evening and least (4.6 log CFU/m^3) in the morning and evening. During the wet season, THBC ranged from 4.9-5.2 log CFU/m^3 in polluted sites, with the highest count (5.2 log CFU/m^3) recorded in morning and least (4.35 log CFU/m^3) in the evening. THBC ranged from 4.35-5.11log CFU/m^3 in the control site, with the highest count (5.11 log CFU/m^3) recorded in evening and least (4.35 log CFU/m^3) in the afternoon.

Figure 3 shows TFC results for air at polluted site and control during the dry and wet seasons. During the dry season, TFC ranged from 4.4-4.8 log CFU/m^3 in polluted sites, with the highest count (4.8 log CFU/m^3) recorded in afternoon and least (4.4 log CFU/m^3) in the morning and evening. TFC ranged from 3.17–3.9 log CFU/m^3 in the control site, with the highest count (3.9 log CFU/m^3) recorded in the morning and least (3.17 log CFU/m^3) in the evening. During the wet season, TFC ranged from 2.5-4.6 log CFU/m^3 in polluted sites, with the least count (2.5 log CFU/m^3) recorded in evening and highest (4.6 log CFU/m^3) in the morning. TFC ranged from 3.3-5.6 log CFU/m^3 in the control site, with the highest count (5.6 log CFU/m^3) recorded in morning and least (3.3 log CFU/m^3) in the evening.

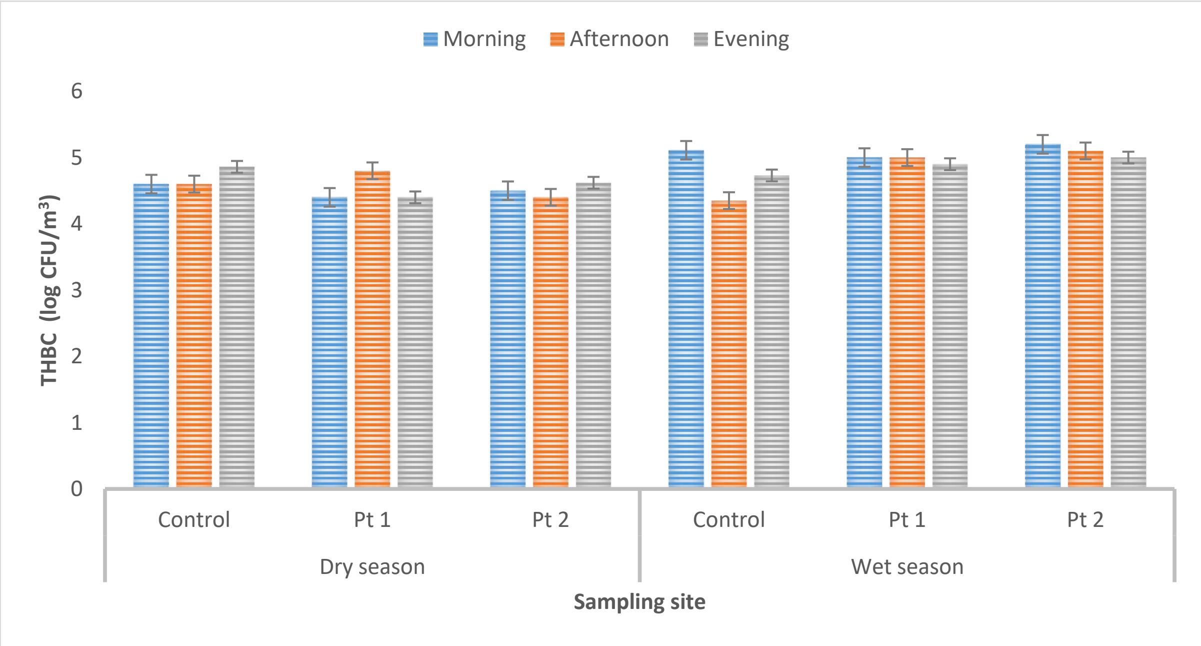

Figure 2: THBC in air samples

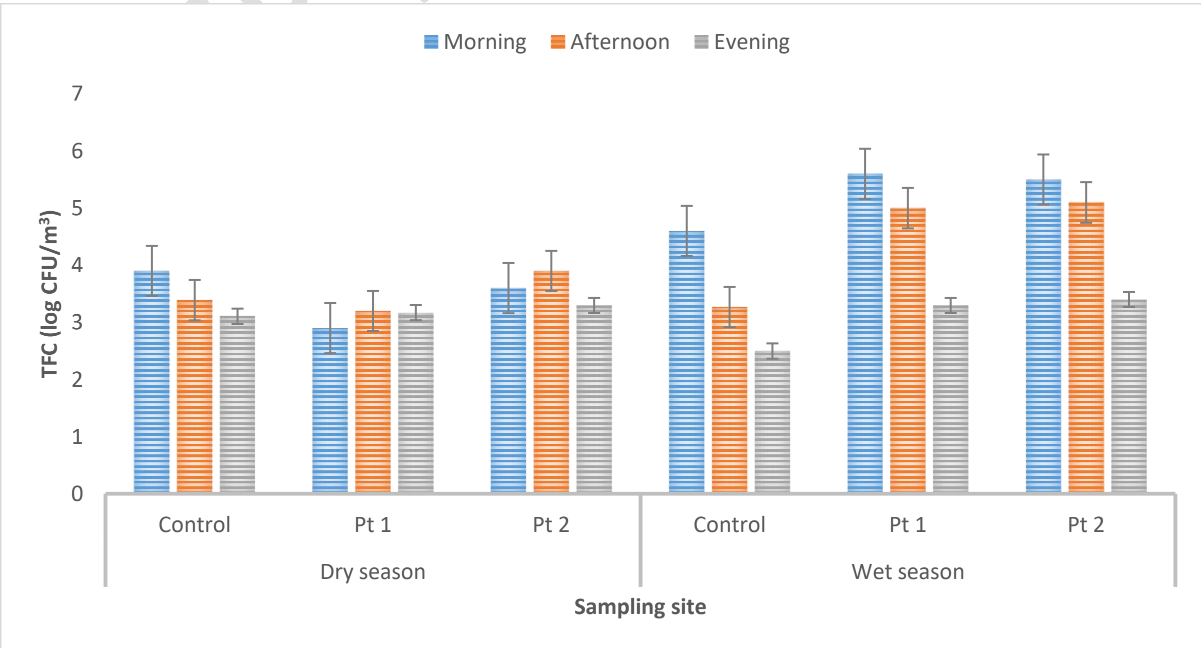

Figure 3: TFC in air samples

Table 3 shows the microorganisms isolated from the air. The bacterial isolates were identified as belonging to five genera: Bacillus, Micrococcus, Pseudomonas, Staphylococcus and Escherichia, while the fungal isolates belong to three genera: Fusarium, Aspergillus and Penicillium.

Table 3. Bacterial and fungal isolates obtained from the air samples

Sample	**Bacteria**	**Mold**
Impacted soil	*Bacillus* sp.	*Aspergillus* sp.
	Micrococcus sp.	*Penicillium* sp.
	Pseudomonas sp.	*Fusarium*
	Staphylococcus sp.	
	Escherichia coli	
Control	*Bacillus* sp.	*Aspergillus niger*
	Citrobacter sp.	*Fusarium* sp.
	Acinetobacter sp.	*Penicillium* sp.
	Pseudomonas sp.	
	Micrococcus sp.	
	Escherichia coli	
	Staphylococcus sp.	

4. Discussion

This study investigated the impact of artisanal refinery operations on the air quality in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria. Air quality assessment was carried out to determine the concentrations of NOx, VOC, CH_4, CO, CO_2, O_3, PM 1, PM 2.5, PM 4, PM 7, PM 10, TSP, SOx, NH_3, H_2S, relative humidity and noise level in the study area. The results show that SOx and NOx concentrations for impacted site for both dry and wet season were above the pristine environment (control site) and above the Federal Ministry of Environment (FMEnv) limits. The results also show that SOx and NOx concentrations in polluted site were more in the atmosphere during the dry season than wet season. SOx and NOx are among criteria air pollutants associated with the formation of acid rain [4]. Concern for these gases (SOx and NOx) and other criteria air pollutants such as O_3, particulate matter and CO, is that they can be dispersed far beyond the point of generation owing to diffusion, and can be inhaled or deposited on biota, with potential to cause severe physiological impairments and diseases [4,5,15,16].

Concentrations of other pollutants (VOC, O_3, H_2S, particulate matter (PM), TSP, noise, air temperature relative humidity, CH_4 and CO_2) in polluted site were more in the atmosphere during the dry season than wet season. This is in agreement with the report by Yakubu [5] and Adoki [17] that levels of air pollutants are influenced by season, with air pollutant occurring mostly in the dry season. With respect to pollutants emanating from artisanal crude oil refineries, the levels during the dry season, tend to be higher in the evenings and morning (early hours) where most of the cooking activities are done. However, the air quality results from the polluted site showed that CO was more in the atmosphere during the wet season than dry season. The various concentrations of monitored parameter (NOx, VOC, CH_4, CO, CO_2, O_3, PM 1, PM 2.5, PM 4, PM 7, PM 10,TSP and noise) were significantly different ($p<0.05$), except SOx, NH_3, H_2S, wind speed, air temperature and relative humidity. With regard to season (dry and wet), concentrations of NOx, VOC, CO_2, O_3, PM 1, PM 2.5, PM 4, PM 7, PM 10,TSP and noise were significantly different ($p<0.05$), while SOx , CH_4, CO, NH_3, H_2S, wind speed, air temperature and relative humidity were not significantly different ($p>0.05$).

The results in the present study agree with values for air quality analysis reported by Ukaegbu et al. [18] in Port Harcourt Metropolis, in which the concentrations of SO_2 and NO_2 exceeded the WHO and FMEnv Standard limits for 24 hours exposure. Onakpohor et al. [4] in their study of the effect of artisanal petroleum refineries in the Niger-Delta similarly established that the activities are sources of significant air pollution, which breached the set limits for NOx and SO_2. Onakpohor et al. [4] reported that the amount of pollutant gases released is a function of the refining capacity of the artisanal refineries. Yakubu [5] reported that soot pollution emanating from artisanal crude oil refining in Rivers State, has increased the pollution burden in the state, especially with respect to particulate matter. Although TSP concentrations in the present study was within acceptable limit, concern still exist for their levels in the air. Scientific studies have consistently reported correlation between fine and coarse PM with lung cancer, chronic lung disease, influenza, respiratory impairment, asthma, coronary artery disease and increased mortality rate [8, 19, 20].

During the dry season, THBC ranged from 4.4-4.8 log CFU/m^3 in polluted sites, and ranged from 4.6-4.86 log CFU/m^3 in the control site. TFC ranged from 4.4-4.8 log CFU/m^3 in polluted sites, and ranged from3.17–3.9 log CFU/m^3 in the control site. During the wet season, THBC ranged from 4.9-5.2 log CFU/m^3 in polluted sites, and ranged from 4.35-5.11 log CFU/m^3in the control site. TFC ranged from 2.5-4.6 log CFU/m^3 in polluted sites, and ranged from 3.3-5.6 log CFU/m^3 in the control site. There was no statistical significant difference ($p>0.05$) in microbial counts between polluted soil and control as well as between dry and wet season. These results thus suggest that artisanal refinery operation does not significantly affect microbial pollution in air. This could be so because of the prevailing meteorological conditions that disperse microorganisms in open spaces [21].

The bacterial isolates were identified as belonging to five genera: Bacillus, Micrococcus, Pseudomonas, Staphylococcus and Escherichia, while the fungal isolates belong to three genera: Fusarium, Aspergillus and Penicillium. Similarly, Nrior and Chioma [9] studied the effect of the black soot on microbial air quality, and identified associated with soot as belonging to five bacterial genera: Staphylococcus, Bacillus, Pseudomonas, Escherichia, *Micrococcus*, just like in the present study. The fungal isolates in that study include species of *Aspergillus, Fusarium* and *Penicillium*. Members of these genera contain species that cause abscess, food poisoning, respiratory diseases and scabby skin syndrome [9].

5. CONCLUSION

This study examined the impact of artisanal refinery operations on the physicochemical and microbiology quality of air in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria and established that the concentrations of NOx and SOx exceeded the set limit by the Federal Ministry of Environment. The microorganisms present belong to genera of bacteria and fungi that contain pathogenic species.

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