FUPRE Journal of Scientific and Industrial Research
Vol.3 (1), 2019
ISSN: 2579-1184 (Print) ISSN: 2578-1129 (Online)

Effects of New Year Eve's Fireworks on the Ambient Air Quality in Woji Community, Port Harcourt, Nigeria

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Abstract

Globally, celebrations of public holidays, religious and traditional festivals, sporting events, political and military victories, and other occasions often include pyrotechnic displays, or fireworks. The effects of fireworks display on the air quality of Woji community, Port Harcourt metropolis during the 2016 New Year Eve celebration has been determined experimentally. Four (4) monitoring sites where firework display is a yearly occurrence were chosen for the study. At each of the identified monitoring site, five (5) air quality monitoring parameters, particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), carbon monoxide (CO) and sulphur dioxide (SO_2) were determined using a series of hand held air quality monitoring equipment. Average value of PM_{10}, $PM_{2.5}$, NO_2, CO and SO_2 was 395.98(μg/m^3), 311.38(μg/m^3), 22.64ppm, 20.23ppm, and 7.32ppm respectively. Levels of measured parameters across all monitoring sites were above regulatory limits. Hourly measured levels of PM_{10}, $PM_{2.5}$, NO_2, CO and SO_2 across all monitoring stations are higher than on four previous air quality studies. Air quality index (AQI) indicates that the air quality in the study area within the study period can be described as unhealthy for active children, women and adults, and people with respiratory disease such as asthma. The federal, state, and local governments must make use of the findings of this study to protect the Nigeria environment.

Keywords: Celebration, New Year Eve, Air Quality, Monitoring, Fire cracker

1. Introduction

Globally, celebrations of public holidays, religious and traditional festivals, sporting events, political and military victories, and other occasions often include pyrotechnic displays, or fireworks (Plimpton, 1984). Festivities such as Guy Fawkes Night in the U.K (Godri *et al.*, 2010), United States, Independence Day (July 4) (Seidel and Birnbaum, 2015), Diwali festival in India (Barman, *et al*., 2008), the Lantern Festival in Beijing (Wang *et al*., 2007), Canada Day (Joly *et al*, 2010), World Cup celebrations in Milan (Vecchi et al., 2008) and at the global level New Year's Eve celebration have been accompanied with serious aerial fireworks (Drewnick *et al.,* 2006). Burning of firecrackers and illumination is a symbol of joy signalling the herald of prosperity and new beginning.

Chemically fireworks/firecrackers contain various organic and inorganic chemicals, such as charcoal, sulphur, potassium, sodium oxalate, manganese, lead, aluminum, iron, strontium nitrate and barium nitrate (Conkling, 1985; Steinhauser *et al*., 2008). The burning of such organic and inorganic chemicals in air also produces gaseous pollutants such as SO_2 and NO_2, and produce huge amount of ambient particulates into the atmosphere that generates dense clouds of smoke (Attri, *et al*., 2001; Moreno *et al*., 2007; Wang *et al*., 2007; Barman, *et al*., 2008). The contribution of the display of fireworks to poor air quality have been largely reported in literature. Examples of some recent findings include: Increase in sub-micron particle mass concentration by a factor of 10 or greater for about an hour following the 2005 New Year's celebration fireworks in Mainz, Germany, and a daily average concentration on January 1 exceeding the European Union PM10 air quality standard of 50 mg/m^3 (Drewnick et al., 2006). Increase in daytime and nighttime PM_{10}, SO_2, and NOx, by factors of 2 x 10^7, during Diwali in Lucknow City, India (Barman, *et al*., 2008). Increase in $PM_{2.5}$ concentrations by a factor of 6 during the 2006 Lantern Day in Beijing (Wang *et al*., 2007). Increase in $PM_{2.5}$ by up to a factor of 50 within the fireworks plume and within 2 km of the launch site during the 2007 Montreal International Fireworks Competition (Joly, *et al*., 2010). Increase in PM_{10} of about 50% during fireworks for World Cup celebrations in Milan in July 2006 (Vecchi et al., 2008).

These short-term air pollution events often pose serious health hazards, especially for asthmatic children (Becker *et al*., 2000) and other respiratory-sensitive groups of the population. More recently, a positive and significant relationship was found between particulate oxidative burden and individual trace metals associated with fireworks firecrackers, suggesting a potential negative impact of firework-emitted particles on human health (Godri *et al*., 2010). Exposure to PM is associated with a broad range of adverse human health effects, mainly affecting the respiratory and cardiovascular systems (WHO, 2003).

Air quality is an important environmental medium that must be continuously monitored and studied so that programs can be initiated that will improve it and to guide citizens in their daily activities. The Federal Hazardous Substances Act classifies fireworks as hazardous, because the explosives can have dangerous side effects, including air pollution, fires, injury, and death (Wang *et al.*, 2007). The Federal Ministry of Environment sets National Ambient Air Quality Standards (NAAQS) for air pollutants (FMENV, 1995) for the purpose of determining if an area is in compliance with the NAAQS and to raise alarm when air quality is forecast to be unhealthy for sensitive groups. There are several studies on water, soil and air quality monitoring due to the transport, industrial and domestic sectors in the Nigeria (Rim-Rukeh, 2014; Rim-Rukeh 2015). But very limited study is known regarding air quality occassioned by fireworks and the uncontrolled burning of the scrap vehicle tyres as a potential contributor for environmental degradation. Hence, the aim of the present study is to assess the contribution of fireworks/firecrackers display during New Year eve celebration within the Woji community.

2. Materials and Methods

2.1 Study Area

This study focussed on the air quality across the different monitoring stations in Woji Community within Port Harcourt metropolis during the 2016 New Year Eve celebration. It investigated concentrations of the following air quality parameters: carbon monoxide, sulphur dioxide, nitrogen dioxide and particulate matter.

Port Harcourt, the present day capital of Rivers State is situated approximately between latitude 04^0 43' and 04^0 57' North of the Equator and between 06^0 53' and 07^0 08' East of the Greenwich Meridian. It has area coverage of about 12,000Ha (NDDC, 2003). The population of the Rivers State is estimated at 5,600,000 (NPC, 2006). The city is a fast growing urban centre and has been described as one of the fastest growing city in the world with a number of industries such as Notore Fertilizer Company of Nigeria, Eleme Petrochemicals Company Limited, Port Harcourt Refining Company Limited, Shell Petroleum and Development Company etc (NDES, 2004). The city is surrounded by patches of islands and creeks. It is bounded to the north by Oyigbo and Etche Local Government Areas, to the south by Okrika Local Government Area, to the east by Okrika and Eleme Local Government Areas and to the west by Emohua Local Government Area (Ayoade, 1988). The climate is predominantly tropical and falls within what can be termed as the subequatorial region due to its proximity to the equator. The mean annual temperature is 28^{0}C with heavy rainfall of 2370.5mm (Gobo, 1998).

Woji community which is located in Obio-Akpor Local Government Area within Port Harcourt metropolis of Rivers State, Nigeria (Figure 1). In terms of geographical coordinates Woji community is located within Latitude 4° 47' 18" North and Longitude 7° 0' 3" East. The choice of Woji Community for the study is based on the fact that the community is rapidly undergoing urbanization and development characterize with changes in lifestyle and increasing population.

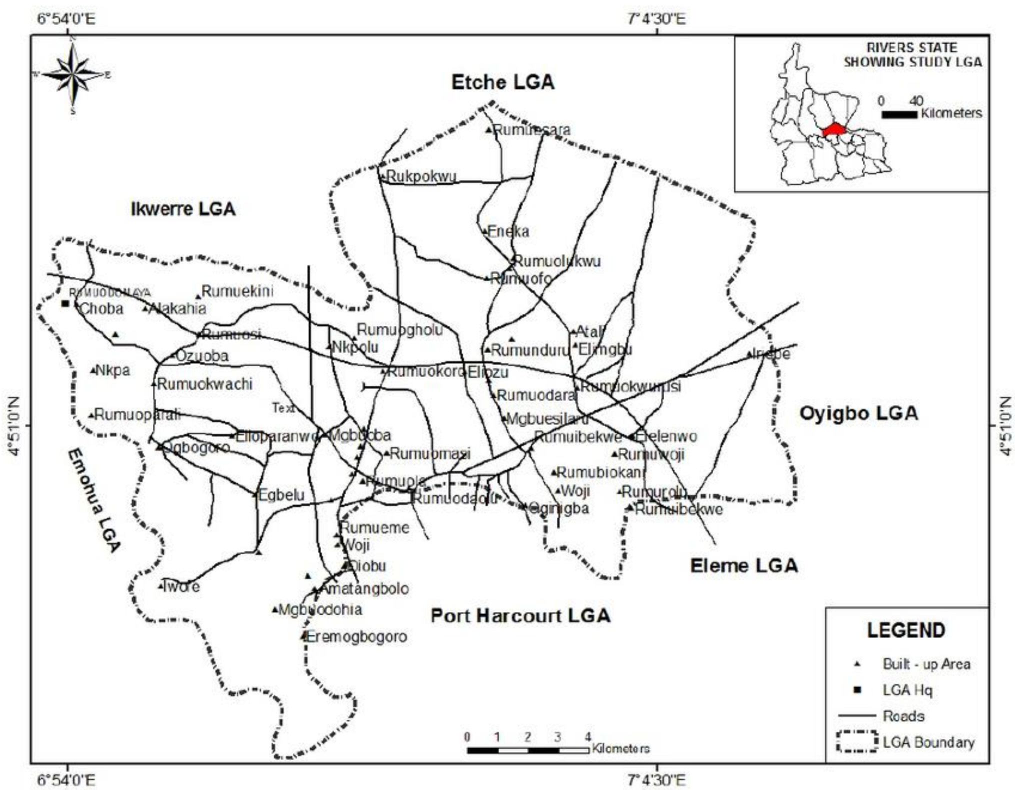

Figure 1: Map of Obio-Akpor LGA of Rivers State Showing Woji Community with map of Rivers State as inset

2.2 Sampling Station Description

Four (4) monitoring stations where fireworks/fire crackers and uncontrolled burning of used vehicles tyres is a yearly occurrence were chosen for the study (Table 1). Positioning at each monitoring site during the data gathering was achieved with the aid of a hand held *Garmin* Global Positioning System (GPS) V, (model CZ 99052-20).

Table 1: Geographical coordinates of air quality monitoring stations

S/No	Monitoring Stations	Geographical coordinates	
		Northing	Easting
1	Woji Junction by Old Aba Road	4^0 51’38’’	7^0 10’13’’
2	Woji Road by Rail way	4^0 51’56’’	7^0 10’27’’
3	Woji Road by Woji Town hall	4^0 52’12’’	7^0 10’47’’
4	Woji Road by YKC Filling Station	4^0 52’51’’	7^0 10’59’’

2.3 Sampling Procedure

At each of the identified monitoring station air quality monitoring parameters; particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), carbon monoxide (CO) and sulphur dioxide (SO_2) were determined using a series of hand held air quality monitoring equipment. The GT-331 VI.04 A Met One Instrument, Inc. Aerosol Mass Monitor Model GT-331 was used in determination of particulate matter (PM_{10} and $PM_{2.5}$). The monitor uses light scatter to measure individual particles instead of clouds like other monitors. The particle information is then grouped into size ranges and converted to mass concentration over 4 minutes at a flow rate of 2.83 L/min into measuring ranges of: <1 micron, PM_{10} mass concentration. Levels of CO, SO_2, and NO_2 were measured using Industrial Scientific Corporation ITX Multi-Gas monitors. Measurements were done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability.

The twelve-hour data gathering period was carried out from early evening starting at 8.0pm on December 31, 2016 and ending at 7.0am on January 1, 2017 (Table 2).

3. Results and Discussion

3.1 Results

Air quality of Woji community monitored within the study period is as presented in Table2.

Table 2: Results of the ambient air quality monitoring

Time (Hr)	Monitoring Stations/Parameters																			
	Woji Junction by Old Aba Road					Woji Road by Rail way					Woji Road by Woji Town hall					Woji Road by YKC Filling Station				
	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (ppm)	CO (ppm	NO_2 (ppm)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (ppm	CO (ppm	NO_2 (ppm	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (ppm	CO (ppm	NO_2 (ppm)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (ppm)	CO (ppm)	NO_2 (ppm)
8.00pm	210	263	0.75	14.0	11.3	301	196	2.31	17.7	16.9	337	234	7.73	19.3	19.4	190	192	0.71	8.7	9.7
9.00pm	280	271	1.72	14.6	12.1	317	221	4.42	19.3	21.2	394	288	7.80	19.7	17.4	221	237	1.82	6.3	10.5
10.00pm	299	288	7.30	15.2	11.2	339	245	8.81	21.4	18.8	479	296	8.30	20.4	23.0	257	241	4.20	6.1	9.3
11.00pm	331	397	8.10	15.9	19.7	356	253	8.97	27.1	23.5	492	312	8.77	26.7	29.1	281	249	5.10	11.8	19.1
12.00am	355	342	11.9	17.8	24.3	441	266	9.91	27.0	33.6	561	339	10.0	30.2	37.0	293	377	6.90	16.4	25.6
1.00am	380	355	11.3	23.0	29.2	560	370	12.0	28.6	41.0	677	416	11.3	28.4	41.2	302	393	7.40	21.2	23.7
2.00am	391	338	9.72	21.7	25.9	571	377	11.4	27.7	37.6	804	442	11.0	31.3	39.6	395	334	7.67	19.7	24.8
3.00am	375	319	8.80	20.3	31.0	552	369	10.7	28.7	33.9	752	483	9.90	29.0	41.3	387	321	5.51	24.0	17.8
4.00am	338	297	7.70	14.6	18.7	479	316	9.70	21.2	23.2	779	472	9.37	27.7	27.6	336	313	6.20	25.6	19.3
5.00am	393	258	6.10	17.7	16.2	410	297	7.10	19.7	27.6	661	417	8.85	23.1	21.0	217	295	7.71	18.5	12.2
6.00am	267	233	5.50	13.2	17.5	373	277	6.52	29.0	19.3	573	397	8.20	29.7	24.5	201	277	6.40	19.2	11.7
7.00am	259	226	3.31	10.2	15.5	315	251	4.40	16.2	22.0	329	329	7.30	16.7	19.7	197	267	4.90	11.0	10.8
Range of values	210 – 393	226 - 397	0.75 – 11.9	10.2 – 23.0	11.3 – 31.0	301 - 571	196 – 377	2.31 - 12.0	16.2 - 28.7	16.9 – 41.0	329 - 804	234 - 483	7.30 – 11.3	16.7 – 31.3	19.4 – 41.3	190 – 395	192 - 393	0.71 – 7.67	6.1 – 25.6	9.3 – 25.6
Average values	323.17	298.92	6.85	16.52	19.38	417.83	286.5	8.02	23.63	26.55	569.83	368.75	9.04	25.18	28.4	273.08	291.33	5.38	15.71	16.21
Regulatory limits (FMENv 1995)	250	150 – 230	0.1	10	0.04 – 0.06	250	150 – 230	0.1	10	0.04 – 0.06	250	150 – 230	0.1	10	0.04 – 0.06	250	150 – 230	0.1	10	0.04 – 0.06

3.2 Discussion

From the results as presented in Table 2, measured levels of PM_{10}, $PM_{2.5,}$ $SO_{2,}$ CO and NO_2 across the monitoring stations were above regulatory limits of 250µg/m^{3,} 230µg/m^{3,} 0.1ppm, 10ppm and 0.06ppm respectively. Obtained values of PM_{10}, $PM_{2.5,}$ $SO_{2,}$ CO and NO_2 in this study may have resulted from the the display of fireworks/fire crackers and uncontrolled burning of used vehicles tyres during the New Year eve celebration. This observation is consistent with that reported in literature (Drewnick *et al.*, 2006; Steinhauser *et al*., 2008). A comparative analysis of obtained results against regulation limits is as illustrated in Figures 1-5. In addition, a comparative analysis of the outcome of this study with that conducted previously on the air quality studies within Port Harcourt metropolis (Zagha and Nwaogazie, 2015; Weli, 2014; Weli and Ayoade, 2014; Robert, 2015) showed higher values of air quality parameters and this may as well be attributed to the events of new year eve celebration (Figure 6.0).

Although, the levels of measured parametrs are higher than the regulatory limits, much higher levels of sub-micron particle mass concentration hourly $PM_{2.5}$ levels climb to ~500 mg/m^3, and 24-hr average concentrations increase by 48 mg/m^3 (370%) have been reported (Seidel and Birnbaum, 2015). Increase in daytime and nighttime PM_{10}, SO_2, and NOx, by factors of 2 x 10^7, during Diwali in Lucknow City, India (Barman, *et al*., 2008). Increase in PM_{10} of about 50% during fireworks for World Cup celebrations in Milan in July 2006 (Vecchi *et al*., 2008). Differential levels in the concentrations of air pollutants may have been related to the quality of fireworks/fire crackers displayed.

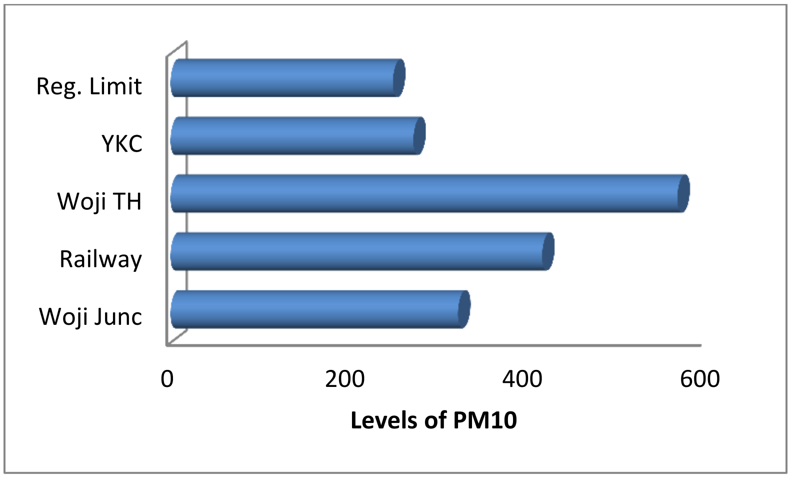

Fig. 1: Measure average of PM_{10} at the Monitoring Stations

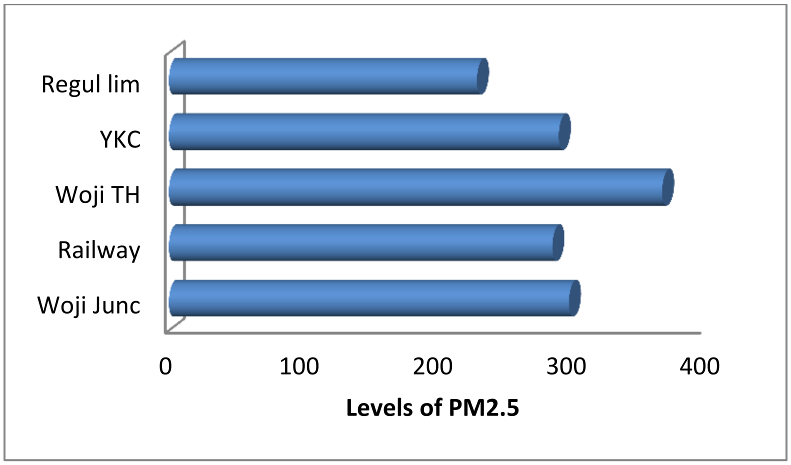

Fig. 2: Measure average of $PM_{2.5}$ at the Monitoring Stations

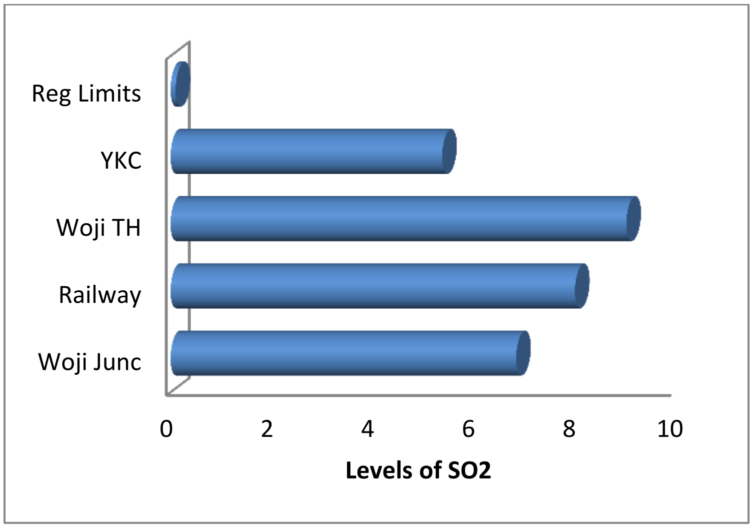

Fig. 3: Measure average of SO_2 at the Monitoring Stations

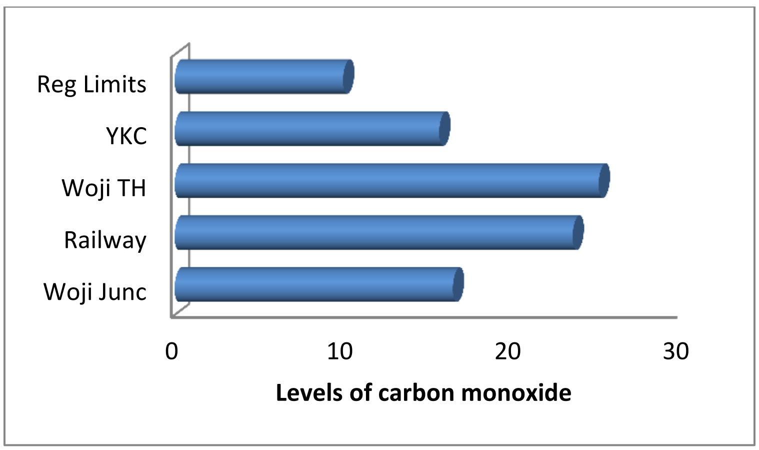

Fig. 4: Measure average of CO at the Monitoring Stations

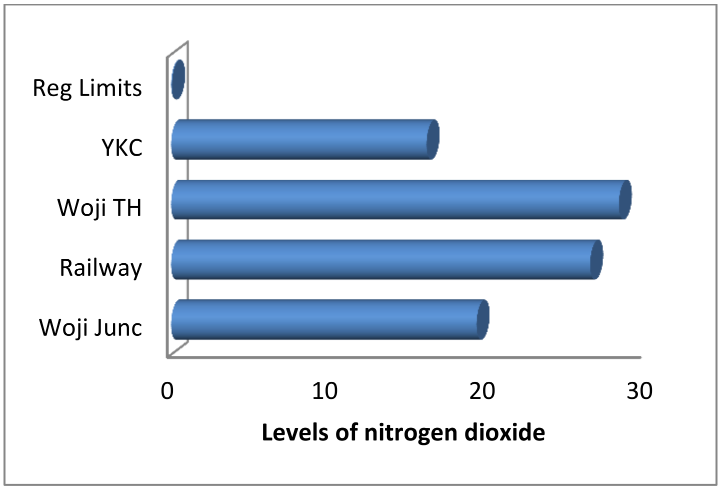

Fig. 5: Measure average of NO_2 at the Monitoring Stations

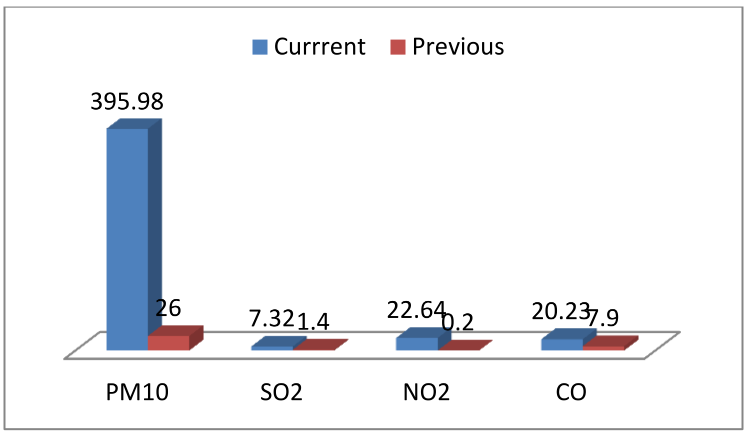

Fig. 6: Comparing mean values of this study and previous study

The observed levels of air quality monitoring parameters may have resulted form the chemical composition of fire crackers because they are made of 75% potassium nitrate, 15% carbon (C) and 10% sulphur (S) (Conkling, 1985; Steinhauser *et al.*, 2008) and hence when burnt in air releases gases such as SO_2, CO_2 and NO_2 (Attri, *et al.*, 2001). In addition uncontrolled burning of used tyres is reported to emit large quantities of particulate matter (Downard *et al.*, 2015).

A pollutant measurement surpassing national ambient air quality standards for a specific averaging time is referred to as exceedance. Adopting the Nepal, Ministry of Population and Environment categorization of five different types of air quality based on the levels based on the levels of PM_{10}: 0-6µg/m^3 as good, 60-120µg/m^3 as moderate, 121-350µg/m^3 as unhealthy, 351 - 425µg/m^3 as very unhealthy and greater than 425µg/m^3 as hazardous (URBAIR, 1997)). The air quality in the study area during the New Year eve celebration can be described as unhealthy.

Gaseous pollutants and huge amount of ambient particulates released into the atmosphere during festive seasons are reported to have health-damaging impacts. For example, adverse health effect has been observed with carbon monoxide concentrations of 12 - 17ppm for 8 hours while prolonged exposure to concentrations of between 200ppm and 800ppm often results in severe headache, dizziness, nausea and convulsions (CCDI, 2001). SO_2 are more toxic because they slowly get absorb in the fine particles and are transported deep into the lung. SO_2 damage the tracheal nasal system (Spengler and Samet, 1991). NO_2 destroys the linings of the respiratory surface and thus reduce the intake of oxygen for the body. It has been found that NO_2 is a deep lung irritant, which generates biochemical alterations and histological demonstrable lung damage in laboratory animals as a result of both acute and chronic exposure (Spengler and Samet, 1991). High concentrations of particulate matters (PM) are known to irritate the mucous membranes and may initiate a variety of respiratory diseases. Fine particulates may cause cancer and aggravate morbidity and mortality from respiratory dysfunctions (CCDI, 2001). PM-10 particulates are able to penetrate and damage people's lungs and cause the worst health problems. In addition, PM can also cause damage to materials by soiling clothing and textiles, corroding metals (at relative humidity above 75%), eroding building surfaces, and discolouring/destroying painted surfaces (Peavy, *et al*, 1985). Generally, asthma sufferers, people with other lung problems, and children are most vulnerable to this pollution (Das, 2004).

Health risk assessment of the results was explored using the guidelines for reporting of daily air quality - air quality index (AQI) (see equation 1) (US EPA, 2006). The descriptor of air quality index is presented in Table 3 and illustrated in Figure 7.

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}(C_P - BP_{Lo}) + I_{Lo} \qquad 1$$

Where: I_P = the index for pollutant P

CP = the rounded concentration of pollutant P

BP_{Hi} = the breakpoint that is greater than or equal to C_P

BP_{Lo} = the breakpoint that is less than or equal to C_P

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

Table 3: Air Quality Index descriptor

These Breakpoints							equal these AQIs…	Category
O_3 (ppm) 8-hour	O_3 (ppm) 1-hour[1]	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)	AQI	
0.000-0.064	-	0.0 – 15.4	0 – 54	0.0-4.4	0.000-0.034	(2)	0 – 50	Good
0.065-0.084	-	15.5 – 40.4	55 – 154	4.5-9.4	0.035-0.144	(2)	51 – 100	Moderate
0.085-0.104	0.125-0.164	40.5 – 65.4	155 – 254	9.5-12.4	0.145-0.224	(2)	101 – 150	Unhealthy for sensitive groups
0.105-0.124	0.165-0.204	65.5 – 150.4	255 – 354	12.5-15.4	0.225-0.304	(2)	151 – 200	Unhealthy
0.125-0.374	0.205-0.404	150.5–250.4	355 – 424	15.5-30.4	0.305-0.604	0.65-1.24	201 – 300	Very Unhealthy
(3)	0.405-0.504	250.5-350.4	425 – 504	30.5-40.4	0.605-0.804	1.25-1.64	301 – 400	Hazardous
(3)	0.505-0.604	350.5-500.4	505 – 604	40.5-50.4	0.805-1.004	1.65-2.04	401 – 500	Hazardous

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0-50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51-100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101-150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151-200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201-300	Health alert: everyone may experience more serious health effects.
Hazardous	> 300	Health warnings of emergency conditions. The entire population is more likely to be affected.

Fig. 7: Air Quality Index Descriptor

The air quality index (AQI) calculated for the Particulate matter($PM_{2.5}$) and (PM_{10}) and Carbon monoxide (CO) is presented in Table 4.

Table 4: Air Quality Index of the Study Area

Parameters/Units	Average concentration of pollutant	Air Quality Index	Air Quality Descriptor
$PM_{2.5}$	311	179	Unhealthy
PM_{10}	323	184	Unhealthy
CO	20	217	Very unhealthy

Using carbon monoxide, the air quality can be described as unhealthy for active children, women and adults, and people with respiratory disease such as asthma and hence people that are sensitive should consider staying indoor especially during new eve celebrations.

3.3 Policy Implications

Yearly, the country witnesses massive importation of fireworks for use during the yuletide season. On December 26 2013 there was banger fire explosion that rocked parts of Jankara Market in Lagos Island. The explosion, which affected many buildings at Ojo Giwa and Okoya Streets, led to the loss of some lives and the destruction of goods and property worth millions of naira. Apart from the Jankara market explosion, banger fire in the past has caused some victims bodily injuries and set property ablaze. Bangers have also been deployed to harass innocent people on the streets during festivities.

Although there is no legislature on the use of fireworks there are still one form of prohibition or another, for example the Nigeria Police Force usually issues orders against the use of fireworks prior to major festivities in the country. The federal, state, and local governments must make use of the findings of this study to protect the Nigeria environment. The following should form the policy thrust:

(i). Fireworks are not on the import prohibition list of the Nigeria Customs Service, their importation must be guided by strict safety regulations. Storage of explosives like fireworks and bangers should no longer be treated with levity as it has been. Importers must be licensed and their warehouses constantly monitored to ensure strict compliance to public safety rules and regulations.

(ii). Enforcement on the ban on the use of fireworks.

(iii). The fireworks are brought into the country because the officials of concerned agencies are not alive to their responsibilities. Such gross dereliction of duty must be checked to avoid bringing in items that can compromise the safety of the citizenry. The leadership of the NCS, SON and the Police should on the top of their duties.

(iv). Enactment of regulations guiding the use of imported fireworkes should be implemented. The Lagos banger fire explosion has also brought to the fore the need to revisit all existing legislations on fireworks and make them more stringent in view of the serious damage unbridled use of banger can cause the country.

(v). When expecting the government to do more to curb pollution, the public should also try to change their mindset and way of living by setting off less firecrackers or abandoning the habit.

Conclusion

This study used observations of PM_{10}, $PM_{2.5}$, NO_2, CO and SO_2 from 4 sites across Woji community that is located within Port Harcourt metropolis to estimate the effects of New Year Eve celebration using fireworks and uncontrolled burning of used vehicle tyres on the air quality of the area. The monitoring was carried out between 8.0pm on 31 of December 2016 and 7.0am on 1 of January 2017 on hourly basis. The main findings are:

1. Hourly measured levels of PM_{10}, $PM_{2.5}$, NO_2, CO and SO_2 across all monitoring stations were above regulatory limits.

2. Hourly measured levels of PM_{10}, $PM_{2.5}$, NO_2, CO and SO_2 across all monitoring stations are higher than on four previous air quality studies.

3. The magnitude and timing of the air quality observed in the course of this study vary from site to site as would be expected given variations in the quantity of fireworks, distances between fireworks displays and air quality monitoring sites, local meteorological conditions, etc.

4. Average value of PM_{10}, $PM_{2.5}$, NO_2, CO and SO_2 was 395.98**(**$\mu g/m^3$), 311.38**(**$\mu g/m^3$),

22.64ppm, 20.23ppm, and 7.32ppm respectively.

5. Air quality index (AQI) indicates that the air quality in the study area within the study period can be described as unhealthy for active children, women and adults, and people with respiratory disease such as asthma.

Acknowledgments

I am grateful to Daniel Igiegie, Efe Ejofodome, Ijeoma Uzo and Mudiaga Akpobi (HSE Department of Tricorr Technologies Limited, Effurun Delta State) for monitoring the air quality at each of the identified site and the Management of Tricorr Technologies Limited, for the release of the Company air quality monitoring equipment at no cost.

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