Sustainability in Environment
ISSN 2470-637X (Print) ISSN 2470-6388 (Online)
Vol. 5, No. 3, 2020
www.scholink.org/ojs/index.php/se

Original Paper

Airborne Particulate Matter Pollution—Knowledge, Perception and Breathing Experiences of Port Harcourt Residents During COVID-19 Pandemic Shutdown

Rogers B. Kanee[1*], Wale. J. Adeyemi[1], Precious N. Ede[2], AKuro. E. Gobo[1], Omosivie Maduka[3], Chibianotu Ojimah[4], David O. Edokpa[2], & Golden Owhonda[5]

[1] Institute of Geo-Science & Space Technology, Rivers State University, Port Harcourt, Nigeria

[2] Department of Geography & Environmental Management, Rivers State University, Port Harcourt, Nigeria

[3] Department of Preventive and Social Medicine, Faculty of Clinical Sciences, University of Port Harcourt, Nigeria

[4] University of Port Harcourt School of Public Health, Port Harcourt, Nigeria

[5] Department of Public Health Services, Rivers State Ministry of Health, Port Harcourt, Nigeria

[*] Rogers B. Kanee, Institute of Geo-Science & Space Technology, Rivers State University, Port Harcourt, Nigeria

Received: August 3, 2020 Accepted: August 20, 2020 Online Published: August 24, 2020

doi:10.22158/se.v5n3p28 URL: http://dx.doi.org/10.22158/se.v5n3p28

Abstract

While millions of deaths are recorded from COVID-19 pandemic infection, the environment continues to benefits from the lockdown of cities. A descriptive cross-sectional survey aimed at assessing residents' knowledge and perception concerning air pollution and breathing experience in Port Harcourt was carried out within 20th-28th of May, 2020. Convenience and purposive non-randomized sampling methods were used to recruit 358 participants. Using descriptive and chi square test analysis, majority (74% and 24%) of the respondents were very aware or aware of air pollution and its health consequences. This varied significantly with sex, age, marital status, occupation and location ($p < 0.05$). Before the city's lockdown, 90.1% of respondents experienced particulate matter deposits on surfaces and during the lockdown; it reduces to 54.1% with significant difference ($p < 0.05$) across residential areas. Hence, age, sex, marital status, occupation and residential area likely to influence higher awareness of air pollution and not duration of stay. Additionally, significant difference in breathing experiences ($p < 0.05$) was noted, with majority reporting poor breathing experience before

lockdown and good during the lockdown. Joint action of governments' policies on air pollution and high awareness among residents could be explored effectively to mitigate air pollution hazards.

Keywords

airborne particulate, black carbon, kap, covid-19, port harcourt

1. Introduction

Clean and healthy ambient air remains an essential physiological need for an effective and efficient human function and well-being (Wang *et al.,* 2015). Globally, ambient air pollution remains a top risk of public health concern, as many people continue to breathe unsafe polluted air. It is ranked the 4th health threat and topmost environmental risk (WHO, 2016), leading to over 7 million annual death attributed to air pollution (WHO, 2016; WHO, 2018), with particulate matter having the topmost health risk contribution among the pollutants (WHO, 2020). Nigeria like most developing countries where air quality continues to decline (WHO, 2016b) is stated to be the 4th worldwide and the 1st in Africa with poor air quality associated with mortality and morbidity burdens (Health Effects Institute, 2018). Unlike Abuja where atmospheric particulate matter has been found to be within acceptable threshold (Obioh et al., 2013; Kanee *et al.,* 2020), the atmosphere of Port Harcourt has been continually noted with saturated airborne particulate matter that far exceeds acceptable limits by over 200% (RSMENV, 2019; Edokpa & Ede, 2019; Ede & Edokpa, 2017; Yakubu, 2017; Akinfolarin, Boisa, & Obunwo, 2017). Since the sudden appearance of soot haze in the atmosphere in 2016 (RSMENV, 2016), the over 3 million residents of Port Harcourt metropolis (Worldpopulationreview.com, 2020) are said to breathe daily air polluted with particulate matter of over 440µg/m^3 contaminated with Polyaromatic hydrocarbons, heavy metals, and other toxic compounds (RSMENV, 2019; Edokpa & Ede, 2019).

In Port Harcourt, petroleum and hydrocarbon exploration and refining remain the foremost source of air pollution, including particulate matter of sizes (PM_{10} and $PM_{2.5}$) and other toxic compounds (Gobo, 2013; Yakubu, 2017; RSMENV, 2019; Edokpa & Ede, 2019). Studies have also estimated quantitatively, high of risk cancers, increase treads of morbidity, mortality and reduction in life expectancies associated with particulate matter pollution on residents (US EPA, 2008; UNEP, 2011; Ebenstein et al., 2017; Fienemika, In, & Best, 2018; RSMENV, 2019; Lelieveld et al., 2020, WHO, 2020a) on residents. The studies were found to be weak for not comprehensively and qualitatively assessing health risks and effects that integrates the perspective of the affected inhabitants (Mudi, Terracini, & Martuzzi, 2014; Maduka & Tobin-West, 2017). An awareness survey is an integrative and representative investigation that collects data from a particular population on what is known, believed, perceived risks, experiences, actions taken and attitudes towards a specific phenomenon that affects the group at or over a time (Zahedi *et al.,* 2014; Wang et al., 2015). The influence of geography and other socio-demographic factors on a peoples' perception, awareness, and behaviors and consequently the group's participatory decisions have been explained by theory of planned behaviour (Arcury & Christianson, 1993; Raudsepp, 2001). Environmental attitude has been stated to allow for exploration into the set of beliefs,

perceptions, interests, awareness or rules that influences pro-environmental and anti-environmental actions of a people (Fernandez-Manzanal, Rodriguez-Barreiro, & Carrasquer, 2007).

During the Corona virus pandemic shutdown, millions of deaths resulting from COVID-19 pandemic have been reported (WHO, 2020b) and anthropogenic, economic, industrial activities and sources responsible for particulate matter pollution were found to be on hold and global air quality observed to improve significantly (Shrestha et al., 2020). And as such, exposed inhabitants such as Port Harcourt residents were likely to have observed different air quality experiences, as against the boom days of industrial and commercial activities. Estimates of about 25 to 40 million Nigerian are said to use digital devices especially smart phones. With internet penetration of 47.1% of the population, it is also stated that Nigerians are among the top users of internet, as over 92.3 million people access the internet, which is also projected to reach 84.4% population penetration by 2023 (Statista.com, 2020). With the lockdown, more people were to have used the internet and digital devices for work, study, transaction, conferences, amongst others, hence collecting data digitally during a pandemic lockdown best suit the study design (De, Pandey, & Pal, 2020). Since there are limited investigations about residents' awareness, attitude and perception of air pollution and respiratory health risks in Nigeria, the study explores the issue, using residents of Port Harcourt metropolis. The study findings could be necessary for the advancement of modern environmental policies, efficient and implementable air pollution mitigations that are acceptable by the public.

2. Materials and Method

2.1 Description and Meteorology of Study Area

The study was conducted in Port Harcourt. Port Harcourt is the capital of Rivers State, located along the Bonny River and 66 km upstream from the Gulf of Guinea. It is located in latitude 04˚ 45'N to 040 60'N and longitude 060 50'E to 080 0'E in southern Nigeria. Port Harcourt metropolis is largely made up of Port Harcourt City and Obio Akpor Local Government Areas with adjourning urban residential and commercial areas of Oyigbo and Eleme (see Figure 3). Port Harcourt is the oil and gas hub of Nigeria and as of 2006 the population of the city of Port Harcourt was 1,481,000 (which is projected to 3,020,000 in 2020), making it one of most densely populated city in Nigeria. Port Harcourt features a tropical wet climate with lengthy and heavy rainy season and very short dry season. Its annual mean temperature is relatively constant (25 °C-28 °C), with little variation across the months of the year, hence its relative humidity (NPC, 2006; Ogbonna, Amangabara, & Ekere, 2007; Chinago, 2020).

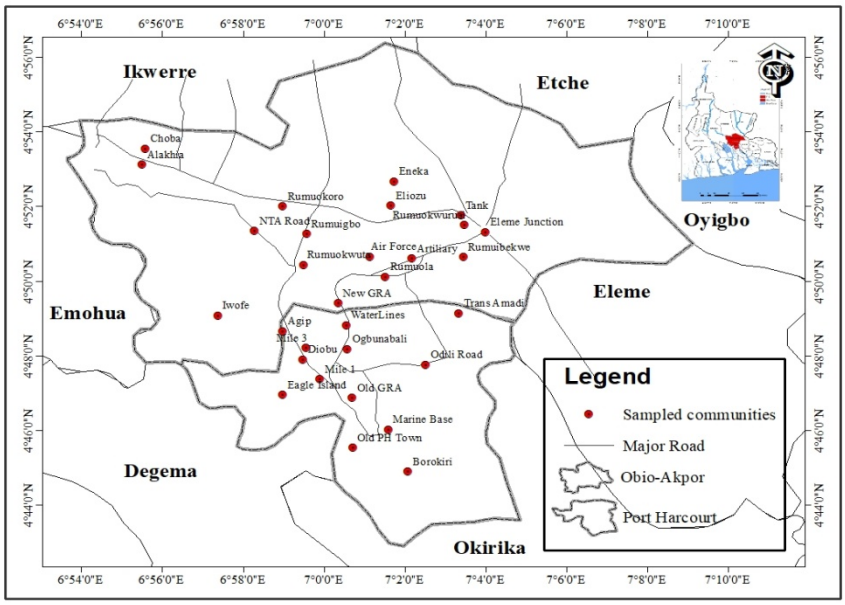

Figure 1. Map of Study Area

2.2 Study Design

The team carried out a descriptive cross-sectional survey aimed at assessing residents' awareness, attitude and perception concerning air pollution and respiratory health risks in Port Harcourt metropolis Nigeria.

2.3 Study Population

The study targeted adult residents of Port Harcourt, 20 years and above, who can use and had access to internet incorporated electronic gadgets (Phones, PCs, and Laptops, etc.)

2.4 Sampling Method

Convenience and purposive non-randomized sampling methods were used to recruit study participants. Convenience; because, the participants were at home during the pandemic lockdown and use of internet-based survey medium was best suited, rather than direct interface. Purposive; because there are empirical evidences of long time airborne particulate matter pollution history and exposure of Port Harcourt residents before the pandemic shutdown.

2.5 Sample Size

Study sample size was estimated using one-sample formula size protocol stated as follows: $n = [Z\alpha^2 (p (1-p)/d^2)]$ were $Z\alpha = 1.95$ (critical value), $p = 0.62$, $d = 0.05$, $n = 358$. The sample proportion (p) of 62% (0.62) prevalence was determined from percentage mean estimates from previous studies (Thaddaeus *et al.,* 2013; Wang *e al.,* 2015; Afolabi *et al.,* 2016; Nwankwo *et al.,* 2018; Zhao *et al.,* 2019; Stephen & Tahiru, 2020) with similar method and objectives.

2.6 Data Collection

The study took place between 20th and 28th of May, 2020. To achieve the study objectives, a modified 20-item thematic structured questionnaires (Qian *et al.,* 2016; Zhao *et al.,* 2019) designed and agreed

upon by the research team was used to collect responses from participants. The response from the participants are achievable within 3-5 minutes. The data collection was done digitally (through Google form link distributed to social media groups' platforms; Whats Apps).

2.7 Data Analysis

Completed responses were downloaded from the Google excel data bases into the Microsoft Excel Spread Sheet (2016), and later exported to Statistical Package for the Social Sciences (SPSS) software, version 26.0, for data analysis. Descriptive analysis (of frequency, mean and standard deviation) was used to describe study participants and their responses. Bivariate analysis was used to show relationships between the outcome variable of air pollution awareness and the independent variables. Chi-squared test was used to assess the bivariate. All statistical tests were done at 95% confidence level, marginal error of 5%, two-tailed and alpha level set at 0.05 to determine statistical significance.

2.8 Quality Control and Assurance

Review from literature reports shows that only handful of studies integrated residents' awareness, attitude and perception towards air pollution and health risks in Nigeria. Thus, the questionnaire was structured and modified to capture the specific needs of the study area. The survey was rigorously pre-tested prior to study implementation to ensure that prospective participants understood the questionnaires well enough. IT and social media experts were consulted to pre-distribute draft questionnaires and their feedback led to modifications in language context, removal and addition of some themes, numbers of themes and items, order of the themes and response time considerations. Before the commencement of data analysis, normality check was done to ensure the research data were normally distributed. Also, the Google form data base was locked to prevent access and modification to the survey form.

2.9 Ethical Consideration

The ethical clearance was obtained from the Policy, Research & Statistics' (PRS) ethics review unit of the Rivers State Ministry of Health (MH/PRS/391/VOL.2/632. 13th Feb., 2020). The purpose of the study and voluntary participation were written for the understanding of prospective respondents in the language (English) understood by the populace. Also, prior to data collection, respondents' consents were sought and obtained through a click option button titled "Do you consent to participate?"

3. Result

3.1 Socio-Demographic Characteristics of Respondents

Three hundred and sixty-two (362) respondents completed the questionnaire online. The age of the respondents ranged between 20 and 80 years. More than half (58.0%) of the respondents were between 30 and 39 years, the average age of respondents was 38.9 years and the standard deviation was 7.9 years. Majority of the respondents were male (65.7%) and married (55.8%). The respondents were of varying occupations, but the three most common groups were public servants (20.2%), academics (16.9%) and health workers (14.6%). The Table 1 also showed that the respondents resided in areas that

spread across Port Harcourt, but majority (22.9%) resided at Rumuo kwuta/NTA Road/Rumuigbo/Rumuokoro/Alakahia/Choba axis of Port Harcourt, and most of respondents (70.7%) have lived in Port Harcourt for 20 years or more. See Table 1.

Table 1. Socio-Demographic Characteristics of Respondents

	Frequency (n=362)	**Percentage**
Gender		
Male	238	65.7
Female	124	34.3
Age Group (years)		
20-29	37	10.2
30-39	210	58.0
40-49	77	21.3
50-59	31	8.6
≥60	7	1.9
Mean age ± SD (years)	38.98±7.93	
Marital Status		
Single	146	40.3
Married	202	55.8
Separated/Divorced	11	3.0
Widowed	3	0.8
Occupation		
Health Worker	53	14.6
Civil Servant	27	7.5
Academic	61	16.9
Public Servant	73	20.2
Security Agent	5	1.4
Student	28	7.7
Clergy	3	0.8
Small Scale Business	43	11.9
Unemployed/Job Seeker	19	5.2
Entertainer	8	2.2
Others	42	11.6
Cluster Settlement		
Old Port Harcourt Township/Marine Base/Borikiri	22	6.1
Old	36	9.9

GRA/Ogbunabali/D-Line/Garrison/Waterlines-Olubasan jo Road		
Mile1/Mile3/Diobu/Eagle Island/Rumueme	41	11.3
Trans-Amadi/Odili Road/Woji Axis	73	20.2
Rumuola/Air Forces/Artilery	9	2.5
New GRA/Agip/Iwofe Axis	56	15.5
Rumuokwurushi/Eleme Junction/Rumuibekwe Axis	17	4.7
Eliozu/Tank/Eneka	20	5.5
Rumuokwuta/NTA	83	22.9
Road/Rumuigbo/Rumuokoro/Alakahia/Choba		
Others	5	1.4
Duration Lived in Port Harcourt		
0-4 years	28	7.7
5-9 years	25	6.9
10-14 years	31	8.6
15-19 years	22	6.1
20 years and above	256	70.7

Awareness of Air Pollution, the health consequences and experience with Black Carbon

It was shown in Figure 2 that 89 (24.6%) of the respondents reported to be aware of air pollution and its health consequences, 269 (74.3%) claim to be very aware, and 4 (1.1%) reported to be poorly aware. In Figure 3 it was shown that 344 (95.0%) had heard about or experienced particulate matter (black carbon) deposits in their areas of residents, 6 (1.7%) had not, and 12 (3.3%) were not sure whether they had heard about or experienced particulate matter (black carbon) deposits in their areas of residents or not (Figure 2 and Figure 3).

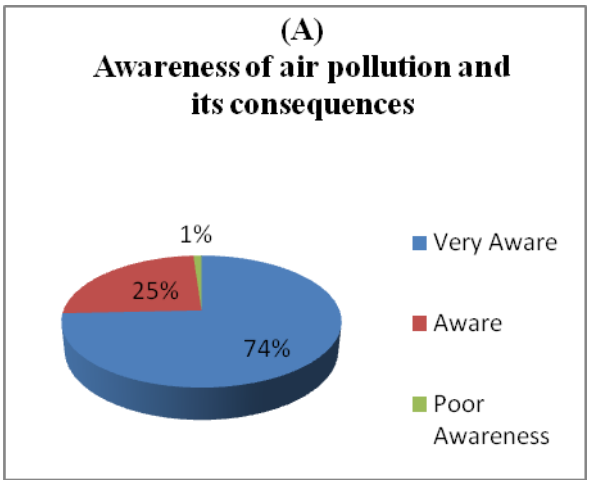

Figure 2. Awareness of Air pollution and Its Consequences

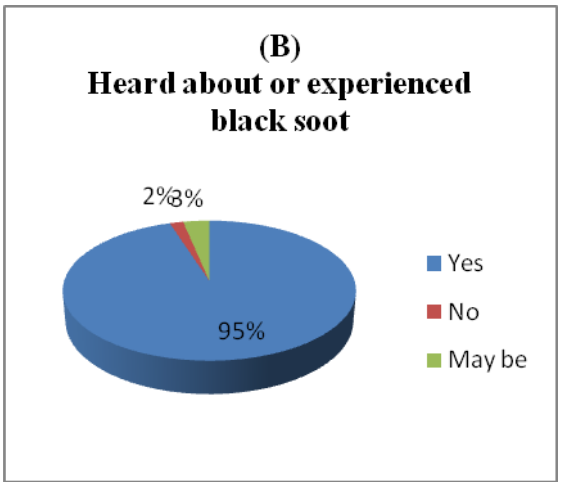

Figure 3. Heard about or Experienced Black Carbon

Before COVID-19 lockdown, 310 (90.1%) of the respondents who reported to have ever experienced black soot experienced the particles on surfaces, 233 (67.7%) experienced black particles inside their nostril, 206 (59.9%) experienced black particles on their feet and palm, and 160 (46.5%) experienced black plumes/smoke in the atmosphere. Similarly, during the lockdown, 186 (54.1%) experienced black particles on surfaces, 89 (25.9%) experienced black particles on feet and palm, 82 (23.8%) black particles inside their nostril, and 54 (15.7%) experienced black plumes/smoke in the atmosphere. However, 127 (36.9%) of respondents who reported to have ever experienced black carbon did not experience of the soot during the lockdown (Figure 4).

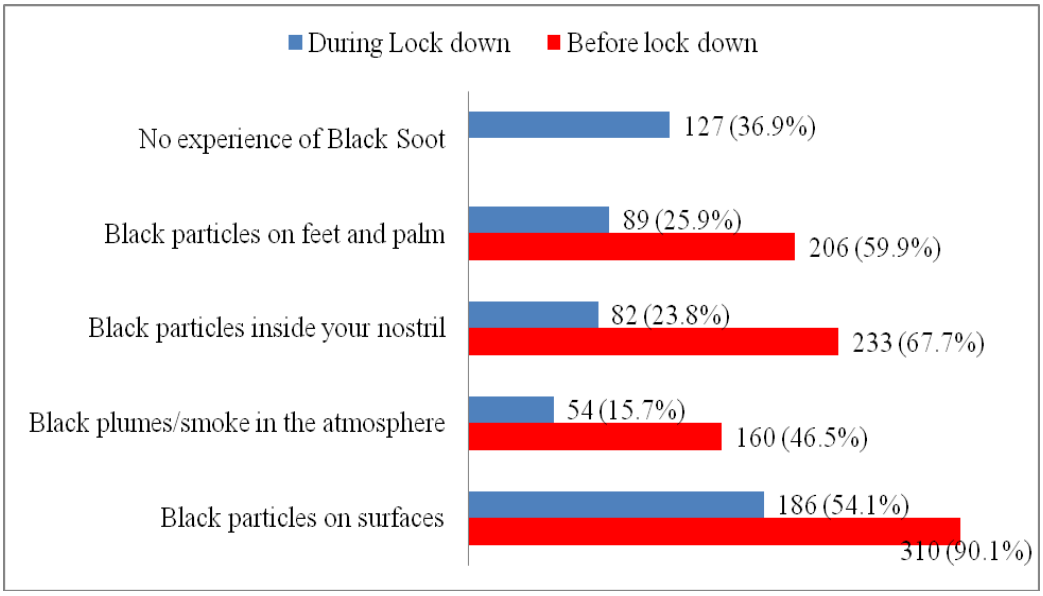

Figure 4. Particulate Matter Experience before and during COVID-19 Lockdown

The Chi-Square test revealed that there was statistically significant difference in respondent's experience of black soot before and during the COVID-19 lockdown, with the experience being more before lockdown compared to during lockdown for the black particles on surfaces (X^2=7.165; p=0.007), for the observation of black plumes/smoke in the atmosphere (X^2=38.509; p<0.001), experience of black particles inside nostrils (X^2=30.666; p<0.001) and observation of black particles on feet and palm (X^2=67.482; p<0.001). See Table 2.

Table 2. Comparing Respondents Experience before and during Lockdown

Experience	Before Lockdown	During Lockdown	X^2 (p-value)
Black particles on surfaces	310 (90.1%)	186 (54.1%)	7.165 (0.007*)
Black plumes/smoke in the atmosphere	160 (46.5%)	54 (15.7%)	38.509 (<0.001*)
Black particles inside your nostril	233 (67.7%)	82 (23.8%)	30.666 (<0.001*)
Black particles on feet and palm	206 (59.9%)	89 (25.9%)	67.482 (<0.001*)

*=Statistically significant.

Perception on sources of particulate matter (black carbon) pollution.

Most (57.7%; n=209) of the respondents perceived that majority of air pollution was from artisanal crude oil refining, 200 (55.2%) perceived it was from vehicular emissions, 173 (47.8%) perceived it was from waste and tyre burning, 163 (45.0%) perceived it was from activities of heavy-duty

machines/asphalt firms/power generators, 119 (32.9%) perceived it was from activities of oil companies, 45 (12.4) perceived it was from household activities, and 14 (3.9%) had others perceptions about source of the pollution. See Figure 5.

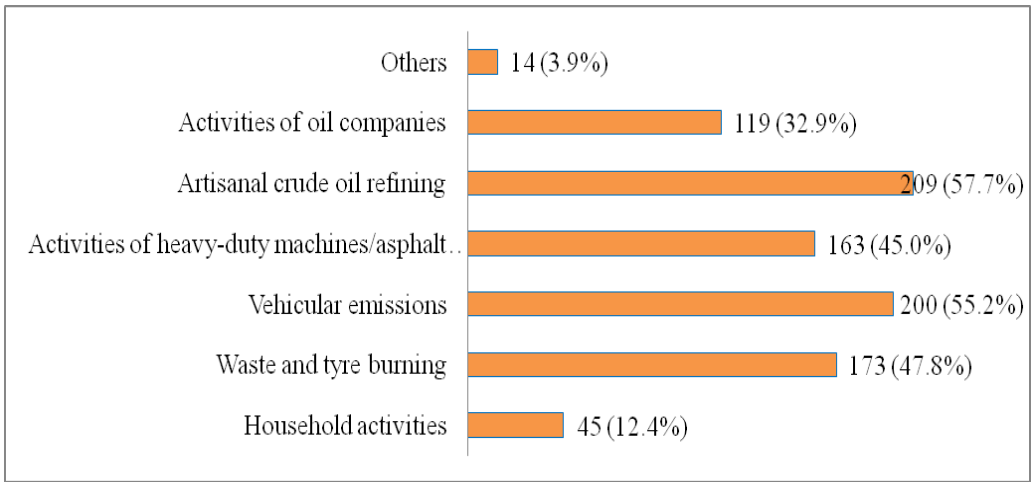

Figure 5. Residents' Perception on Sources of Particulate Matter

Comparing breathing experience before and during lockdown

One hundred and fourteen (31.5%) and 40 (11.0%) of the respondents rated their breathing experience before COVID-19 lockdown as good and very good respectively, and 123 (34.0%) and 37 (10.2%) rated theirs as poor and very poor respectively. However, 48 (13.3%) could not rate their breathing experience before the lockdown. Similarly, 171 (47.2%) and 114 (31.5%) of the respondents rated their breathing experience during the lockdown as good and very good respectively, and 31 (8.6%) and 7 (1.9%) rated theirs as poor and very poor respectively, while 39 (10.8%) could not rate their breathing experience during the lockdown (Figure 6).

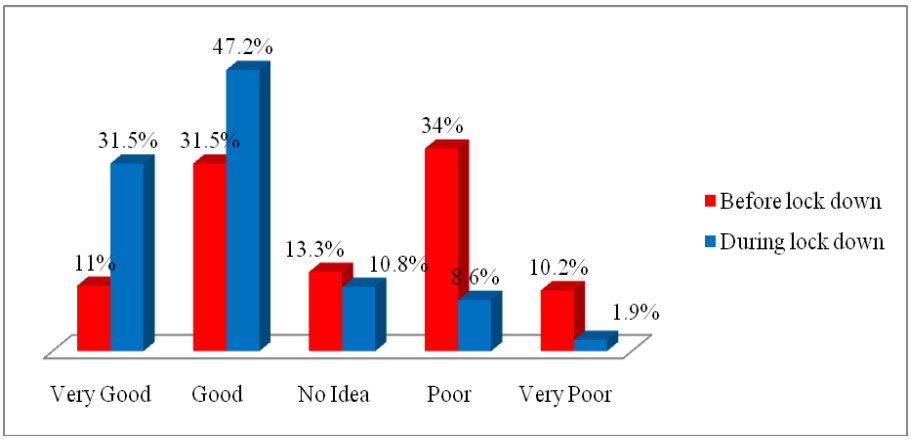

Figure 6. Breathing Experience before and during Lock Down

The level of anxiety about health and air quality self-rated revealed that anxiety level was very high in

89 (24.6%) of respondents, high in 166 (45.6%) of respondents and mild in 75 (20.7%) of respondents. Twenty (5.5%) of respondents reported not having any form of anxiety, while 12 (3.3%) had no idea of their anxiety level about health and air quality (Figure 3.5). It was also noted that only 216 (59.7%) of the respondents desired to have good air quality even after the COVID-19 lockdown (Figure 7).

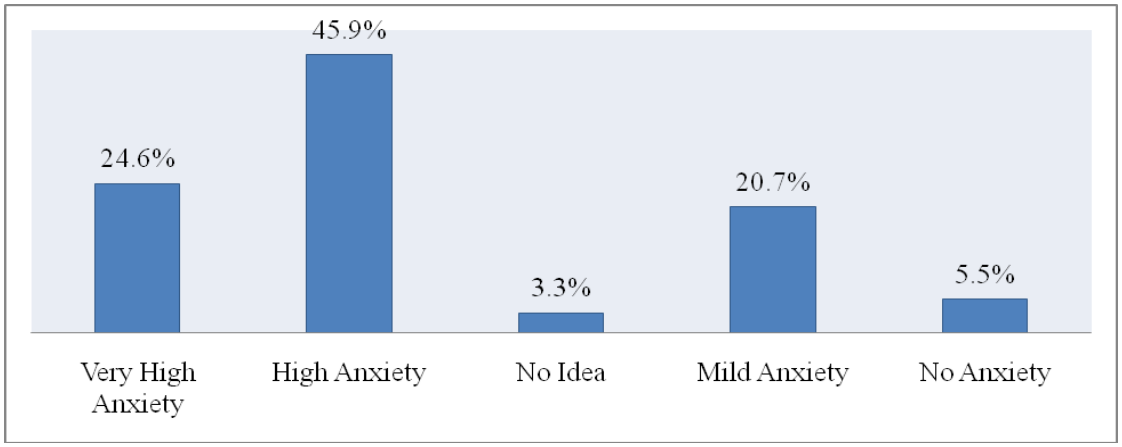

Figure 7. Level of Anxiety about Health and Air Quality before Lock down

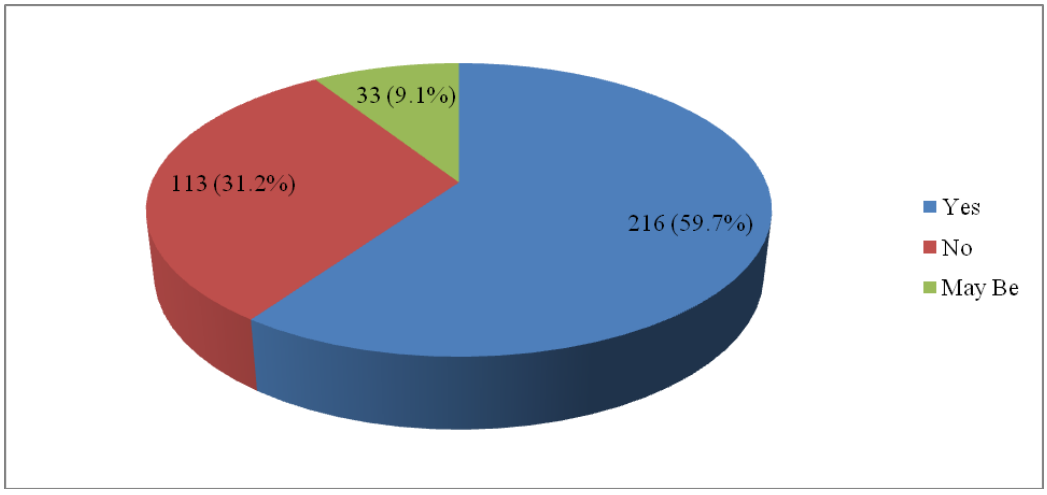

Figure 8. Desire to Experience Good Air Quality Post COVID-19 Lockdown

Socio-demographics characteristics of respondents associated with particulate matter (black carbon) awareness

Table 3 is the Chi-Square cross-tabulation test showed the relationship between respondent's awareness about particulate matter (black carbon) and their socio-demographic characteristics. Among the 344 respondents that had experienced or heard of black carbon, 223 (64.8%) were males and 121 (35.2%) were females, but there was no statistically significant difference in the proportion of males and females, who had the experienced or heard of black carbon, compared ($p=0.107$; $X^2=2.602$). It was also

shown that black soot experience was highest among respondents between 30-39 years of age (57.3%, n=197), then 21.8% (n=75) among those between 40-49 years, 9.9% (n=34) among those between 20-29 years, 9.0% (n=31) among those between 50-59 years, and least among those who were 60 years and above (2.0%, n=7), but there was no statistical significance (p=4.337, X^2=0.362) was noted. Marital status also did not show statistical significance even when over half of the respondents who were aware were married (p=2.259; X^2=0.520). However, there was a statistically significant difference in black carbon experience across respondent's who lived in Port Harcourt. Awareness about black carbon was highest (71.8%, n=247) significantly among respondents who had lived in Port Harcourt for 20 years and over (p=19.134; X^2=0.001). Respondent's cluster settlement (p=13.307; X^2=0.149) and occupational status (p=15.843; X^2=0.104) did not show any statistically significant difference. See Table 3.

Table 3. Experience and Awareness about of Black Carbon across Socio-Demographic Characteristics of Respondents

Variable	Experienced or heard about black carbon		X^2	p-value
	Experienced (%)	Not experienced (%)		
Gender				
Male	223 (64.8)	15 (83.3)	2.602	0.107
Female	121 (35.2)	3 (16.7)		
Age Group				
20-29 years	34 (9.9)	3 (16.7)	4.337	0.362
30-39 years	197 (57.3)	13 (72.2)		
40-49 years	75 (21.8)	2 (11.1)		
50-59 years	31 (9.0)	0 (0.0)		
60 years and above	7 (2.0)	0 (0.0)		
Marital Status				
Single	136 (39.5)	10 (55.6)	2.259	0.520
Married	194 (56.4)	8 (44.4)		
Separated/Divorced	11 (3.2)	0 (0.0)		
Widowed	3 (0.9)	0 (0.0)		
Duration Lived in Port Harcourt				
0-4 years	25 (7.3)	3 (16.7)	**19.134**	**0.001***
5-9 years	25 (7.3)	0 (0.0)		
10-14 years	25 (7.3)	6 (33.3)		

15-19 years	22 (6.4)	0 (0.0)		
20 years and above	247 (71.8)	9 (50.0)		
Cluster Settlement				
Old Port Harcourt Township/Marine Base/Borikiri	22 (6.4)	0 (0.0)	13.307	0.149
Old GRA/Ogbunabali/D-Line/Garrison/Waterlines-Olubasanjo Road	35 (10.2)	1 (5.6)		
Mile1/Mile3/Diobu/Eagle Island/Rumueme	41 (11.9)	0 (0.0)		
Trans-Amadi/Odili Road/Woji Axis	70 (20.3)	3 (16.7)		
Rumuola/Air Forces/Artilery	8 (2.3)	1 (5.6)		
New GRA/Agip/Iwofe Axis	52 (15.1)	4 (22.2)		
Rumuokwurushi/Eleme Junction/Rumuibekwe Axis	17 (4.9)	0 (0.0)		
Eliozu/Tank/Eneka	20 (5.8)	0 (0.0)		
Rumuokwuta/NTA Road/Rumuigbo/Rumuokoro/Alakahia/Choba	74 (21.5)	9 (50.0)		
Others	5 (1.5)	0 (0.0)		
Occupation				
Health Worker	47 (13.7)	6 (33.3)	15.843	0.104
Civil Servant	27 (7.8)	0 (0.0)		
Academic	58 (16.9)	3 (16.7)		
Public Servant	73 (21.2)	0 (0.0)		
Security Agent	4 (1.2)	1 (5.6)		
Student	26 (7.6)	2 (11.1)		
Clergy	3 (0.9)	0 (0.0)		
Small Scale Business	41 (11.9)	2 (11.1)		
Unemployed/Job Seeker	19 (5.5)	0 (0.0)		
Entertainer	8 (2.3)	0 (0.0)		
Others	38 (11.0)	4 (22.2)		

*=Statistically. Significant.

4. Discussion

Airborne particulate matter (black carbon) pollution remains a major threat to human health and environmental challenge across most cities of the world. Children, infants, pregnant women, the elderly and outdoor workers are found to be most vulnerable to poor air quality, especially from criteria air pollutant such as particulate matter (Perera *et al.,* 2002; WHO, 2006). Economic development in Port Harcourt brought about largely by oil exploration, crude oil refining, petroleum and hydrocarbon driven industrial ecology has also conveyed along with it a sequence of complex social and environmental

issues. This study attempts to assess Port Harcourt inhabitants' KAP of air borne particulate matter pollution as it relates to health before and during COVID-19 pandemic lockdown of the city, as well Government policies on air quality. The study aims to utilize the findings to impact on Port Harcourt environmental and health policies and improve the situation of soot haze plaguing it over the years. Evidence-based and data driven decisions are important factors in successful implementation of environmental policies.

Contrary to the study by Cheng (2017), the study findings showed that majority (74% and 24%) of the respondents were either very aware or aware of air pollution and its health consequences. This links to similar studies (Thaddaeus *et al.,* 2013; China, Wang *et al.,* 2015; Afolabi *et al.,* 2016; Minghui *et al.,* 2019; Stephen & Tahiru, 2020), in which high level of awareness on air pollution was recorded. It is worth mentioning that inhabitants of Port Harcourt are highly aware of air pollution and the consequences it poses to their health. This outcome is likely to result from long term exposure to air pollution and residents' experience of sudden emergence of black particulate matter (popularly called black soot) in the atmosphere of Port Harcourt from late 2016 (Ede & Edokpa, 2019; RSMENV, 2019), 95% of the respondents noted experiencing black particulate matter in their homes and work places. This could result from respondents' long term stay in the city, as majority of the respondents (70.7%) had lived in the city for over 20 years, This long term stay was found statistically significant in influencing individual's experience of black soot in the city and this Suggest that they have knowledge of the ambient air quality condition before the soot haze and during the lockdown. Awareness creation is a critical factor in air pollution mitigation (Lizuka, 2004; Stephen & Tahiru, 2020). More than half (68.2%) of the respondents were young (20-39 years) and being young was significant in influencing high awareness of air pollution among the age group compared to older age groups. This finding agrees with report by Minghui *et al.* (2019) and Stephen and Tahiru (2020) as against studies by Jia and Cai (2014) and Kim, Yi and Kim (2012) which recorded low awareness among young people. Increase awareness among younger people could result from young people being more used to social and electronic media that rapidly circulate information, as against older generations that are obsessed to conventional media for information (Qian et al., 2016; Stephen & Tahiru, 2020). Being aware of air pollution and its health consequences at young age is likely to enhance mitigation measures, as young people possess the exuberance and energy necessary for environmental and air pollution activism (Morar & Peterlicean, 2012; Stephen & Tahiru, 2020). The finding also noted a wide gender disparity between male (65.7%) and female (34.3%) participation in the study, with males being more aware of air pollution and its health consequences (see Table 1). The statistical difference suggests that males are likely to take action on environmental issues than females. On the contrary, studies have shown that women are more at risk of air pollution and other environmental hazards and toxicity than males (Maureen, 2006; Hyunok et al., 2010).

Across occupation, we found that, awareness of air pollution and its implication on health was significantly high among public servants, the academic and health workers and low among the clergy,

entertainers and security personnel. The former high awareness could be due to routine work on policy documents, research and refresher trainings related to environmental issues. Poor awareness among the latter group reveals the need for consistent engagement with the religious leaders, entertainers and artists as well as security personnel as these groups have influence on the people and environmental issues in this part of the world. The study finding showed that there was statistical difference on awareness and residential area, with residents in Trans-Amadi/Odili Road/Woji Axis of Port Harcourt having more awareness compared to residents in other residential clusters. This could explain high reports of activities of illegal crude oil business, security personnel setting ablaze into the atmosphere seized petroleum products (RSMENV, 2016; Yakubu, 2017; RSMENV, 2019). Proximity to the creek, source of crude oil refining, activities of security personnel as well as climatic factors that determines dispersion and distribution of particulate in the ambient are likely to influence experience of black carbon and awareness of air pollution and toxicity to health (Ede & Edokpa, 2019; RSMENV, 2019). The Table3 shows that respondent could live for over 20years in Port Harcourt and experienced black carbon, yet have poor awareness on air pollution and its health consequences; hence, age, sex, marital status, occupation and residential area are likely to influence perception and awareness of air pollution and not duration of stay in the city. This contradicts findings by Bickerstaff and Walker (2001), Brody, Peck, and Highfield (2004) and Thaddaeus *et al.* (2013).

Unlike places such as Abuja (Obioh *et al.,* 2013; Kanee *et al.,* 2020), the atmosphere of Port Harcourt before the COVID-19 lock down have been continually found be saturated with airborne particulate matter (black carbon) that deposits on surfaces (RSMENV, 2019; Edokpa & Ede, 2019; Ede & Edokpa, 2017; Yakubu, 2017; Akinfolarin, Boisa, & Obunwo, 2017). The study result (Figure 4) showed that residents observed a remarkable drop (from 90.1% to 54.1%; 59.9% to 25.9; 67.7% to 23.8% and 46.5% to 15.7%) in black particles on surfaces, on feet and palm, inside of nostrils and black plums in the atmosphere during the lockdown. In addition, 36.9% of the respondents stated that they did not experience any form of particulate matter pollution during the lockdown. This finding suggests that anthropogenic and industrial activities responsible for generating air pollutants were likely halted, hence reduction in pollution. The significant difference ($p < 0.05$) of reported particulates on surfaces between pre-lock down and during lock times also agrees with reports of reduction in air pollution during the pandemic lock of cities across the world (Isaifan, 2020; Sneha, 2020; NASA, 2020; Aurelio *et al.,* 2020, Rui & Acheng, 2020; Shrestha *et al.,* 2020).

Among the major sources of air pollution, respondents mentioned artisanal crude oil refining, and vehicular emissions most often than others. It was also observed that there were relative concerns about waste and tyre burning at dumpsites, industrial plants and activities of oil companies as sources of air pollution were expressed, with few persons reporting household activity as a source of air pollution. This is similar to previous studies (Howel *et al.,* 2003; Thaddaeus *et al.,* 2013; Mudi, Terracini, & Martuzzi, 2014; Maduka & Tobin-West, 2017; Ngo *et al.,* 2018; Arku *et al.,* 2018; Ede & Edokpa, 2018; RSMENV., 2019) in which outdoor industrial activities were mostly responsible for air pollution.

Unlike in Europe where indoor air pollution resulting from household activities such as cooking and environmental tobacco smoke remains a major health threat (Hyunok Choi *et al.,* 2010), resident of Port Harcourt reported lower contribution of indoor activities to air pollution. However, the sources of air pollution reported are mostly industrial and municipal dependent and less of individual contribution. Hence mitigation could largely be subjected to Government and corporate industries policies and practices.

In this study, there was significant difference in breathing experience before and during the lockdown. Majority of the residents reported high anxiety relating to their health and poor air quality before the lockdown. While most respondents reported poor breathing experience before the lockdown, majority reported good breathing experience during the lockdown. This implicates reports from previous studies (Lercher, Schmitzberger, & Kofler, 1995; Wallner, Hunziker, & Kienast, 2003; Thaddaeus *et al.,* 2013; Afolabi *et al.,* 2016; Arku*et al.,* 2018) in which respiratory challenges due to poor air quality were observed. Rise in ambient load of Particulate Matter (PM_{10}) by 10 µg/m3 have been reported to decrease life expectancy by 0.64 years (Ebenstein, Greenstone, & Zhou, 2017; Edokpa & Ede, 2019; kanee *et al.,* 2020) and inhabitants in hydrocarbon and petroleum industrial ecology exposed to ambient air particulates are said to be more at risk of cardiopulmonary morbidity and mortality (Mudi, Terracini & Martuzzi, 2014; Maduka & Tobin-West, 2017). Also before the lock down, the ambient air of Port Harcourt was saturated with soot haze (RSMENV, 2016; Akinfolarin, Boisa, & Obunwo, 2017; Yakubu, 2017; RSMENV., 2019; Ede & edokpa, 2019) with increase in trend of respiratory morbidity and mortality among children (Perera et., 2006; Zhang et al., 2011; Gao et al., 2013; Patelarou, & Kelly, 2014; Fienemika, In, & Best, 2018) and the general population (RSMENV, 2019; Llieveld et al., 2020) have been documented. However, while health burdens relating to virus infection continue to be on the increase during COVID-19 shut down of cities across the world, reduction in diseases and deaths associated with air pollution have been reported (Isaifan, 2020). Hence residents (60%) reporting better breathing experience and desire for the continuation of such air quality in post COVID-19 era, could be justified. As removal of fossil fuel emission is said to increase worldwide mean life expectancy by 1.1 (0.9-1.2) years and 1.7 (1.4–2.0) years by eliminating all potentially manageable anthropogenic emissions (Llieveld et al., 2020) such as particulates from crude oil refining, gas flaring, vehicular and heavy duty industrial machines and open waste burnings at dump sites.

There are some limitations for this survey. Firstly, this survey was rapidly conducted within the 9 days of lock down in Port Harcourt and was done online. The short timing and poor access to power and internet could have limited participation of more residents. Secondly, the survey participants were limited to those with internet incorporated devices. Residents with no such devices may express different KAP. Thirdly, as the KAP survey contained little (or no) questions relating to residents' protective practices (wearing of nose mask, use of handkerchiefs to cover nostrils, use of window vent, ACs, high tech indoor air cleaners, etc.) and source of fuel for domestic use (stove, fire wood, electric, gas, generators, etc.). Class, income level, tribe, religion and education level were not assessed due to it

sensitivity and feedbacks from the pre-test/pilot. Lastly there were limited quantitative air quality data to triangulate with the survey findings. Thus, application of these findings to other areas needs to be done with caution while further studies remain necessary.

5. Conclusion and Recommendation

Majority of the respondents are aware of air pollution and its health consequences and have experienced soot haze in Port Harcourt before the lockdown. Unlike other places, younger people showed more awareness than the older age groups. Young people should be targeted as agent of positive change on air pollution. The need for massive health awareness and environmental education among females, artist and entertainers, the clergy and men of the security agencies remains pertinent.

From the respondents, the significant difference in breathing experienced and particulate matter pollution observed before and during the lockdown shows that, anthropogenic activities were largely responsible for air pollution in the city. Corporate industrial, especially crude oil refining and municipal sources were mostly attributed as source of air pollution, with household practices contributing less.

High level of anxiety before lockdown and the desire or clean air post COVID-19 lock down explains inhabitants' concerns over potential health effects of particulate matter pollution. Hence, the joint action of up to date Government's policy on air pollution and high awareness among residents could be effectively utilized to mitigate the persistent hazard of air pollution in Port Harcourt.

Abbreviation

EPA: Environmental Protection Agency

KAP: knowledge, attitudes, and practices

RSMENV: Rivers State Ministry of Environment

ETS: Environmental tobacco smoke

WHO: World Health Organization

Acknowledgement

The Lead Author of this research paper, Mr Rogers Kaneesincerely appreciates this Journal platform for the opportunity given to publish this paper as well as other Authors for their notable contributions in making this work a success.

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