IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 16, Issue 2 Ser. II (February 2022), PP 01-11
www.iosrjournals.org

Impact of Black Soot on Public Health of Residents in Woji Community of Rivers State

Christopher Obi Obi[1] and Ejikeme Ugwoha[1,2]*
[1]*Centre for Occupational Health, Safety & Environment, Institute of Petroleum Studies, University of Port Harcourt*
[2]*Department of Civil & Environmental Engineering, University of Port Harcourt*
**Corresponding Author's Email Address: ugwohaej@gmail.com*

Abstract
This paper assessed the impact of black soot on public health of residents in Woji Community of Rivers State. Air quality assessment was carried out to determine heavy metal, total petroleum hydrocarbon and polyaromatic hydrocarbon concentrations in soot particles in the atmosphere of the study area. Predominant complaints/symptoms of residents as well as frequencies of diseases associated with soot inhalation before and after 2016 were inquired from health centres. Copies of questionnaire were administered to residents to determine the perceived impact of soot on their health. Data were analysed using frequencies, percentages, and Chi-square contingency test. Findings revealed higher concentrations of chromium in the five sampling points (10.932 ppm, 10.773 ppm, 25.615 ppm, 30.802 ppm, 12.448 ppm) than in the control point (5.905 ppm) and the World Health Organization's permissible limit (0.0005 ppm). Predominant complaints/symptoms of residents included severe catarrh, nasal congestion, frequent cough, chest pain, difficulty in breathing, fever, headaches, etc. Some residents (42%) believed that their health had deteriorated compared to the years before 2016, 19.9% were not sure of any such deteriorations while 37.9% believed that their health had not deteriorated. Overall, there was a statistically significant difference in the frequency of respiratory tract infections of patients in the years before and after 2016 at 95% probability level.

Keywords: *Black soot, Public health, Impact, Woji Community, Residents, Air quality assessment, Artisanal refinery*

Date of Submission: 10-02-2022 Date of Acceptance: 25-02-2022

I. Introduction

Artisanal refineries have been established in the Creeks of the Niger Delta Region of Nigeria in recent years to fulfil local demands for refined petroleum products. Such refineries are small, homemade structures that distil stolen crude oil over a particular range of boiling points to manufacture low-quality petroleum products (Stephen, 2020). Since the procedure is relatively unprofessional and does not meet international crude oil refining requirements, it contributes to hazards and emissions (Ogele and Egobueze, 2020). On average, a typical artisanal refinery produces approximately forty to sixty diesel drums and seven hundred and forty litres of premium motor spirit (PMS) called petrol every day according to individuals familiar with the industry. The size of the bush refineries varies. Small sites aim to draw investment from women and individuals with low amounts of capital, whereas big sites are typically owned by developers because they are normally capital-intensive (Stephen, 2020). The size of the local refining company explains why stiff opposition, or an unexpected backlash are faced by campaigns to end this risk. Research reveals that the local economy is worth around $28 million a month, or $336 million a year. This far exceeds the taxes from local governments hitting impacted communities and makes refining by far the highest valued local business (Stakeholder Democracy Network, 2014). Artisanal refining of petroleum products has been a source of income for young people. It has created job opportunities for communities and filled the supply deficit in the Niger Delta with refined petroleum. Communities perceive artisanal refining as doing what they can to thrive in the absence of mainstream livelihoods in the face of extraordinary exploitation by political leaders (Stakeholder Democracy Network, 2014).

The black soot that has been prevalent since 2016 in Port Harcourt has been related to artisanal refining, security agencies' destruction of discontinued petroleum products, and the use of the poor-quality fuels produced from artisanal refineries has the huge potential of contributing to soot (Stephen, 2020). Soot is a result of incomplete petroleum hydrocarbon combustion. If a hydrocarbon is combusted or burned, the main component that comes out of it is carbon dioxide and water. Furthermore, thick black smoke is created primarily from elemental carbon (soot). It is interesting to remember that the coastal communities south of Port Harcourt

have around 217 artisanal refineries (Banzorwa et al., 2018). It is believed that the bulk of soot comes from the incessant and indiscriminate burning of tankers, vessels, artisanal refining sites and other oil laden containers.

Particulate matter pollution is one of the deadliest forms of air pollution (Weidman and Marshall, 2012). Studies suggest that significant public health problems are posed by fine particles. According to the Environmental Protection Agency, fine particles can penetrate deep into the lungs and have been related to a wide variety of serious health effects, including premature death, heart attacks and strokes, as well as acute bronchitis and children with exacerbated asthma. The American Lung Association adds that cancer, developmental and reproductive disruption can be caused by respiratory particle toxicity (Weidman and Marshall, 2012). Kids, the elderly, low-income families and individuals with pre-existing heart and lung conditions are the most disadvantaged. There are also adverse impacts in healthy adults and individuals of lower socioeconomic status (Weidman and Marshall, 2012). Thus, this study assessed the impacts of black soot on public health of residents in Woji Community. The study objectives were to determine the concentration of Heavy Metals, Polyaromatic Hydrocarbons (PAH) and Total Petroleum Hydrocarbons (TPH) in soot particles in the atmosphere of the study area; ascertain from Health Centres/Clinics the predominant complaints/symptoms of residents in the study area as well as the frequencies of diseases associated with the inhalation of soot particles in air between the years before and after 2016; and inquire directly from the residents about their perception of any impact(s) the black soot has on their health.

II. Methodology

2.1 Research Design

The study adopted both experimental and cross-sectional research designs. Accordingly, air sampling and analysis, questionnaire administration, interviews and published online articles were used for data collection.

2.2 Study Area

This study was conducted in Woji Community. Woji Community is located between Latitudes 4° 49.9336' N and 4° 49' 56.0172" S and Longitudes 7° 2.9419' E and 7° 2' 56.5116" W. It is one of the districts that make up Obio/Akpor Local Government Area of Rivers State in Nigeria. The community occupies an area of around $10km^2$ ($10,317,279.38m^2$) and had a population of 6,635 from 1991 census record, and a projected population of 14,779 in 2020. The Ikwerre people are the original indigenous inhabitants of the community. Woji Community is close to the creeks where most artisanal refining take place resulting in the black soot production. Woji residents are traders, businessmen and women and industry professionals. There are many hospitals, clinics, and health centres which residents and visitors go to for treatment. They include the Model Primary Health Care Centre, Data Medical Centre, St. Catherine's Specialist Hospital, Divine Grace Clinic/Maternity, Grace and Mercy Clinic and St. Mary's Hospital and Maternity. Most professionals in Woji Community work in Banks, Schools, Hospitals, Clinics and Health centres, as well as Oil and Gas companies located in Trans-Amadi Industrial layout. The Map of Woji Community showing the locations of the five Sampling Points and one Control Point as well as the Hospitals/Health Centres visited is shown in Figure 1.

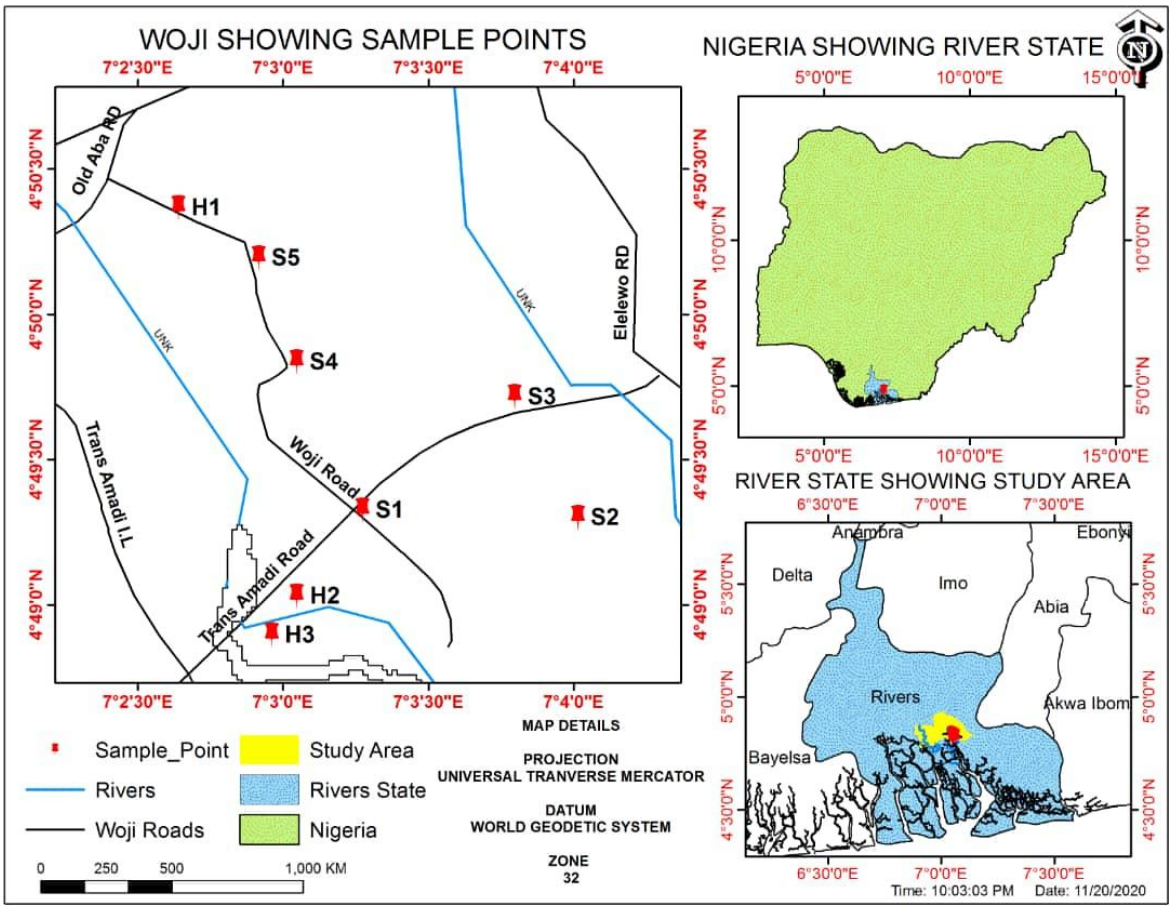

Figure 1: Map of Woji Community showing sampling points and hospitals visited

2.3 Study Population

The target population for the study was the residents in Woji Community which was a projected estimate of 14,779 persons.

2.4 Sampling Techniques and Sample Size Determination

The simple random sampling method was adopted in selecting the respondents upon whom the questionnaire was administered. The population of Woji Community was projected from 6,635 in 1991 according to the National Population Commission of 1991 to 14,779 in 2020. The sample size was calculated using Taro Yamane Equation.

$$n = \frac{N}{1 + N(e)^2} \qquad (1)$$

where n is the sample size, N is the study population, and e is the marginal error (0.05).

Accordingly, a sample size of 390 Woji Community residents was obtained for the study.

2.5 Methods of Data Collection

The study used both primary and secondary sources of data. Primary data were collected from air quality assessment and questionnaire administration. Secondary data were obtained from medical records from the different health centres and clinics in the study area.

2.5.1 Air Quality Assessment

Active air sampling was carried out to determine the concentration of heavy metals, polycyclic aromatic hydrocarbons (PAH) and total petroleum hydrocarbons (TPH) in soot particles in the study area. The selected heavy metals were cadmium (Cd), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As) and lead (Pb). A Minivol Portable Air Sampler was used to trap soot particles onto a filter paper. Five (5) sampling points were selected and one (1) control point which was located far from the study site on the leeward side of wind direction. Correspondingly, five (5) samples and one (1) control sample were obtained. Samples were taken from every $2km^2$ of land area for 3 hours per sampling point for two days. Samples were taken to the laboratory for analysis.

For heavy metal analysis (digestion), 0.5g of the soot samples were weighed and placed in a 125ml beaker, 100ml of distilled water and 0.5ml of Nitric acid (HNO_3) were added. Samples were finely ground and

sieved through a 20mm/10 mesh sieve. 5ml of hydrochloric acid (HCl) was added to the beaker and the samples were heated on a stream bath in a well-ventilated hood until the volume reduced to 15ml, making certain that the samples did not boil. The samples were cooled, and the solids were filtered out, thereafter they were quantitatively transferred to a 100ml volumetric flask. The digested sample assay was conducted using atomic absorption spectrophotometry (AAS) to assess heavy metal concentrations.

For Polyaromatic hydrocarbon and total petroleum hydrocarbon analysis (extraction), 10.0 + 0.1g of each sample was weighed into a clean 50ml extraction bottle. 40ml dichloromethane (DCM) (extraction solvent) was added into the bottle. The samples were agitated/stirred in a shaker and the extract was allowed to settle. The extracted mixture was passed through a filter paper containing 5g of activated silica gel and 5g of sodium sulphate into the vial, ready for injection for Gas Chromatography Mass Spectrometer (GCMS) and Gas Chromatography Flame Ionization Detector (GCFID) analysis carried out to determine concentrations of PAH and TPH respectively.

2.5.2 Questionnaire Administration and Retrieval

A questionnaire was used as the research instrument for data collection on the impacts of the black soot on public health of residents in the study area. The questionnaire was designed as Google Forms and links to it were randomly sent to the email addresses and social media platforms of respondents which were eighteen (18) years of age and above. There were twenty-four (24) questions in the questionnaire. The time for questionnaire filling was approximately five (5) minutes. Completed copies of the questionnaire were submitted and retrieved electronically. Based on the information gathered, analyses were made, and conclusions drawn.

2.5.3 Health Centres and Clinics Records

Visits were made to the health centres/clinics in the study area with a reputation for high rate of patient visits. One health centre/clinic per day in order to find out the predominant health complaints and symptoms of residents in the study area. Interviews were adopted as the research instrument for data collection. Interview sessions were brief, lasting between 10-15 minutes. Clinical records were examined to compare the frequencies of diseases associated with the inhalation of soot particles in the years before and after 2016. Difference(s) between them were noted. Doctors, Nurses and Laboratory Scientists were engaged.

2.6 Methods of Data Analysis

Data collected from copies of the questionnaire, results from the air quality assessment and information gathered from health centres were analysed using descriptive statistics (frequencies and percentages) and inferential statistics (Chi-Square test).

III. Results and Discussion

3.1 Socio-demographic Characteristics of Respondents

Three Hundred and Ninety (390) copies of questionnaire were administered to the residents in the study area and three hundred and fifty-one (351) valid copies were returned, given a response rate of 90%. The respondents were heterogeneous in nature, there were more males (63%) than females (37%). 44.5% of the respondents were between the ages of 26-35 years, 26.5% were between 36-50 years, 21.9% were between 18-25years while 7.1% were above 50 years. Therefore, the youths made up a significant portion of the population. The majority of the population had Bachelor degrees followed by Master's Degree, very few had PhD and SSCE. Professionals and Small Business Owners (Traders) were predominant in the population making up a total of 70.1%.

The interview sessions were carried out in three, non-consecutive days. Health Practitioners (Doctors) were interviewed in the Health Centres and Clinics of the study area, one for each Health Centre. 66.7% of the doctors were males while 33.3% were females. All doctors were resident doctors and had similar responses to the questions that were asked. Clinical records of the frequencies of respiratory tract infections of patients were also obtained for five consecutive years before 2016 and from 2016 to November 2020.

3.2 Air Sampling and Analysis

Table 1 shows the concentrations of heavy metals in the soot particles. There were no concentrations detected for Arsenic in the five samples and control sample. Cadmium concentrations in the samples were higher than that of the Control sample. Cadmium concentrations in Samples 1, 2 and 4 were higher than the annual average permissible limit for Cadmium while those of Samples 3 and 5 were lower. Chromium concentrations in the Samples were higher than both the Control sample and the 24-hour averaged permissible limit; the concentrations in Samples 3, 4 and 5 being more than twice that of the Control sample. The concentrations for Copper, Lead and Nickel in the Samples were also lower than those of the Control sample but higher than the annual average permissible limit for Lead only.

The trend of heavy metal concentrations found in this study is similar to what was reported by Kalagbor et al. (2019). However, while Kalagbor et al. (2019) analyzed the carcinogenic health hazards of the

heavy metals using the target hazard quotient (THQ) and the incremental lifetime cancer risk (ILCR) and found that their presence in the environment puts children and residents in the metropolis of Port Harcourt at risk of various types of cancers, this study assessed the public health impact of black soot on residents of Woji Community.

Table 1: Concentrations of heavy metals in soot

Sample	Location	As (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Pb (ppm)	Ni (ppm)
S1	YKC	ND	2.366	10.932	11.033	1.132	1.344
S2	ABEC	ND	2.734	10.773	9.503	0.739	0.138
S3	Eze-Gbakagbaka	ND	0.666	25.615	2.106	1.127	0.204
S4	Town Hall	ND	3.469	30.802	8.520	0.483	0.042
S5	Elijiji	ND	0.276	12.448	2.607	0.722	0.069
Control	Obiri-Ikwerre Flyover	ND	BDL	5.905	0.416	BDL	BDL
NESREA/WHO Stds (TWA)		1.96 (annual)	1.09 (annual)	0.0005 (24 hrs)	-	0.0002 (24 hrs)	8.33 (annual)

BDL – Below Detectable Limit; ND – Not Detected; TWA – Time Weighted Average

The concentration of total petroleum hydrocarbons (TPH) in soot is shown in Table 2. In the Control sample, TPH concentration was below detection limit. Consequently, the TPH concentrations were greater in all five samples than the Control sample. Table 3 shows the concentrations of polyaromatic hydrocarbons (PAH) in soot in the study area. There was no PAH concentration detected in the control sample hence the PAH concentrations of the five Samples were higher than that of Control sample.

The predominant complaints/symptoms of residents in the study area as found out by this study include Fever, Chest Pain, Difficulty in Breathing, Nasal Congestion, Headaches, Body aches, etc. which are respiratory related. These complaints/symptoms are similar to the health risks found out to be associated with exposure to heavy metals, TPH and PAH in ambient air. Studies reveal that exposure to lead has been shown to affect the nervous system of developing babies. Quite high exposure to lead will trigger death (National Institute for Occupational Safety and Health, 2018). Long-term exposure to arsenic can cause cancer of the lungs. Arsenic and arsenic derivatives have been listed as carcinogenic to humans by the International Organization for Studies on Cancer (IARC) (World Health Organization, 2020). Some of the adverse health effects from hexavalent chromium exposures include nasal cancers and ulcerations (National Toxicology Program, 2018). Long-term exposure to copper can cause irritation of the nose, headaches and dizziness. Intentionally high uptakes of copper may cause death. Acute inhalation exposure (high levels over a short period of time) to cadmium can result in flu-like symptoms (chills, fever, and muscle pain) and can damage the lungs. Chronic exposure (low level over an extended period of time) can result in lung disease (Occupational Safety and Health Administration, 2020). Inhalation of dust containing nickel had resulted in adverse health effects such as chronic bronchitis, diminished lung capacity, lung and nasal cancer (Agency for Toxic Substances and Disease Registry, 2015a). Animal studies have shown effects on the lungs, central nervous system, developing foetus, and reproductive system from exposure to TPH compounds. In humans, one TPH compound (benzene) has been shown to cause cancer (leukaemia) (Agency for Toxic Substances and Disease Registry, 2015b).

Table 2: Concentrations of total petroleum hydrocarbons (TPH) in soot

Sample	Location	TPH (ppm)
S1	YKC	27.59865
S2	ABEC	22.14873
S3	Eze-Gbakagbaka	3.44089E-1
S4	Town Hall	18.56955
S5	Elijiji	22.21615
Control	Obiri-Ikwerre Flyover	0.00000

Table 3: Concentrations of polyaromatic hydrocarbons (PAH) in soot

Sample	Location	PAH (ppm)
S1	YKC	5.40659E-1
S2	ABEC	1.51034E-1
S3	Eze-Gbakagbaka	1.85351E-2
S4	Town Hall	2.02358E-1
S5	Elijiji	1.83921E-1
Control	Obiri-Ikwerre Flyover	0.00000

3.3 Interviews and Clinical Records

The results of the interviews with the medical practitioners in the health centres and clinics revealed that the predominant symptoms or complaints are respiratory related. The interviewed doctors mentioned frequent complaints and symptoms such as cough, catarrh, nasal congestion, fever, headache, chest pain and difficulty in breathing. All doctors attested to the fact that there have been frequent cases of respiratory diseases, cardiovascular diseases, nervous system dysfunctions in recent times (2016 - 2020), the most common ones being common cold, respiratory tract infections, and high blood pressure/hypertension which could lead to stroke. Cases of premature death have not been reported because autopsies are not common in this part of the world. The interviewed doctors all agreed that there has been a surge especially in cases of respiratory tract infections and common cold, looking at inpatients and outpatients loads/records.

Out of the Health Centres/Clinics visited, only one had computer-based health records of patients as far back as the years before 2016 with monthly and yearly records of respiratory tract infections for patients under different Health Maintenance Organizations (HMOs) (Table 4). Data were extracted on the number of cases of respiratory tract infections in the five consecutive years before 2016 and from 2016 to November 2020. The other health centres/clinics had case files containing inpatient and outpatient health records. The case files were arranged according to patient number and not according to year. There were case files on asthma, pneumonia, common cold, high blood pressure/hypertension and seizures for children.

All interviewed health care professionals believed that a significant relationship existed between the black soot in the atmosphere of Woji Community and the increased rate of the aforementioned diseases. In fact, one of them noted that it was almost the same time when residents started noticing changes in air quality, that there was an increased rate of respiratory tract infections among patients. Another was of the view that because of continuous artisanal crude oil processing, people should expect a rise in the number of cases as the years go by. Others opined that the long-term effects of the inhalation of soot particles in air should be a cause for worry and could result in increase of cases of lung failure and chronic pulmonary obstructive diseases (COPD).

To reduce the impact of the black soot on residents' health, the doctors noted that residents could only accomplish little, namely closing of their windows at night, not staying outside at night, using ACs and fans indoors with limited windows open. It was agreed that the bulk of the work and the solution to the menace lies with the government taking practical steps to curb the activities generating the soot like artisanal refining, burning of tyres at slaughterhouses and at festive periods, phasing out rickety cars, public awareness campaigns and the introduction and increase of renewable energy sources, etc.

The Chi-Square contingency test performed on data in Table 4 showed that the calculated chi-square from the contingency table was 17.86 greater than the critical chi-square (9.45) at 95% probability level. Therefore, the null hypothesis is rejected and the alternative hypothesis which states that there is a statistically significant difference in the frequency of respiratory tract infections of patients in the years before and after 2016. Thus, it is concluded that soot in the atmosphere is causing a lot more public health challenges in recent times than it was in the years before 2016.

Table 4: Cases of respiratory tract infections of patients under certain HMO before and after 2016

Before 2016	No. of cases	After 2016	No. of cases
2011	20	2016	50
2012	21	2017	59
2013	50	2018	48
2014	30	2019	59
2015	34	2020	35

3.4 Questionnaire response analysis

Figures 2 to 9 show responses from respondents on the eight research questions that guided this study. Figure 2 shows that majority of respondents (74.4%) believed that the soot had impacted on their health while

25.6% believed that the soot had no impact whatsoever on their health. Figure 3 indicates that 13.4%, 39.6%, and 25.1% of the respondents were able to describe the soot's impact on their health as high, medium and low, respectively. Those who were not sure if the soot had any impact on their health and who were of the opinion that the soot had no impact on their health made up the minority (14.5% and 7.4%, respectively). Figure 4 shows that among all the respiratory diseases associated with the inhalation of the black soot, common cold was the most experienced in recent times, followed by asthma, bronchitis, pneumonia, and lung damage/cancer. However, 17.7% of the respondents had not experienced/suffered from any of the respiratory diseases in recent times. Figure 5 shows that 70.7% of the respondents had not heard of premature deaths in recent times while 29.3% had.

Figure 6 indicates that high blood pressure/hypertension was the most experienced cardiovascular disease by respondents in recent times (16.2%) followed by stroke (6.3%), cardiac arrest (4.6%), and coronary heart disease (4.3%). Heart failure was the least heard of in recent times (3.1%). A greater percentage of the respondents (70.1%) had not experienced or suffered any of the cardiovascular diseases in recent times. Figure 7 shows that dizziness (51%) and nausea (41.9%) have been the most widespread nervous system dysfunctions recently. Other nervous system dysfunctions such as seizures, Alzheimer's, multiple sclerosis, Parkinson disease, and coordination problems are less widespread. Figure 8 indicates that the majority of the respondents (42.2%) were of the opinion that there had been a deterioration in their health after 2016 compared to before 2016, but 19.9% were not sure of any such deteriorations in their health, while 37.9% were of the opinion that their health had not deteriorated in any way. Figure 9 shows that 51.9% of respondents were not sure if their deteriorating health could be attributed to the soot menace, 29.9% were of the opinion that their deteriorating health could be attributed to the soot while the minority (18.2%) believed that their deteriorating health was not as a result of the black soot. This means that there is a high possibility that the deteriorating health of the residents can be attributed to the black soot in the atmosphere of the study area.

The above observations are found to be in agreement with previous related studies (Highwood and Kinnersley, 2006; Grahame et al., 2014; Srinivasarao and Muralikrishna, 2014). According to Srinivasarao and Muralikrishna (2014), soot particles in the air are contributing factors in respiratory diseases and that the fine particles (<3μ) are the worst causes of lung damage due to their ability to penetrate into the deep air passage. Highwood and Kinnersley (2006) also noted that black carbon, largely from combustion processes, contributes to poor air quality and induces respiratory and cardiovascular problems. A critical review by Grahame et al. (2014) found that black carbon from various sources appeared to be causally involved in lung cancer, and cardiovascular mortality, morbidity, and perhaps adverse birth and nervous system effects.

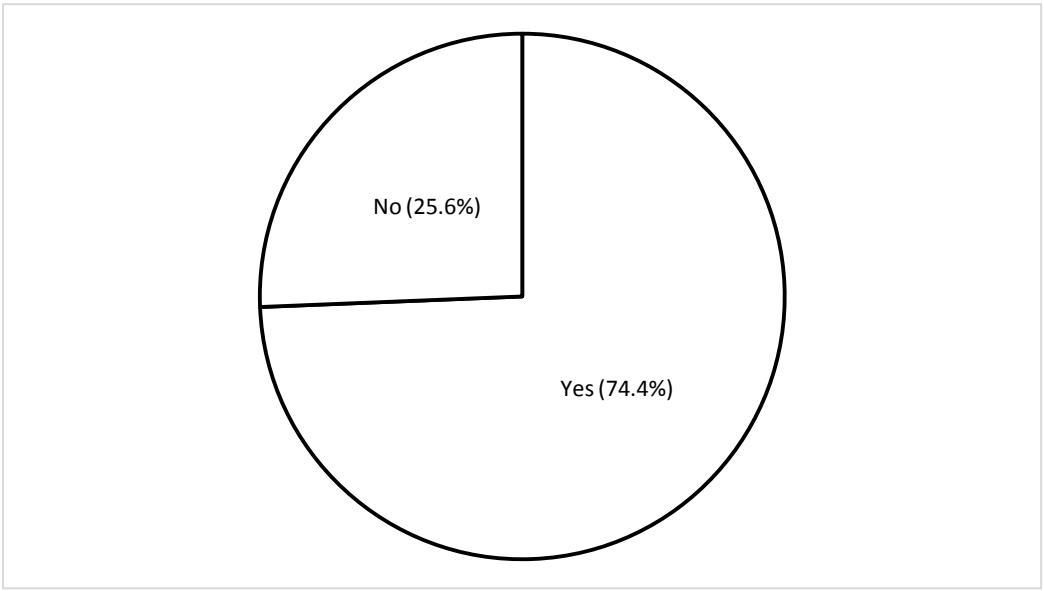

Figure 2: Response to whether soot had impacted on residents' health

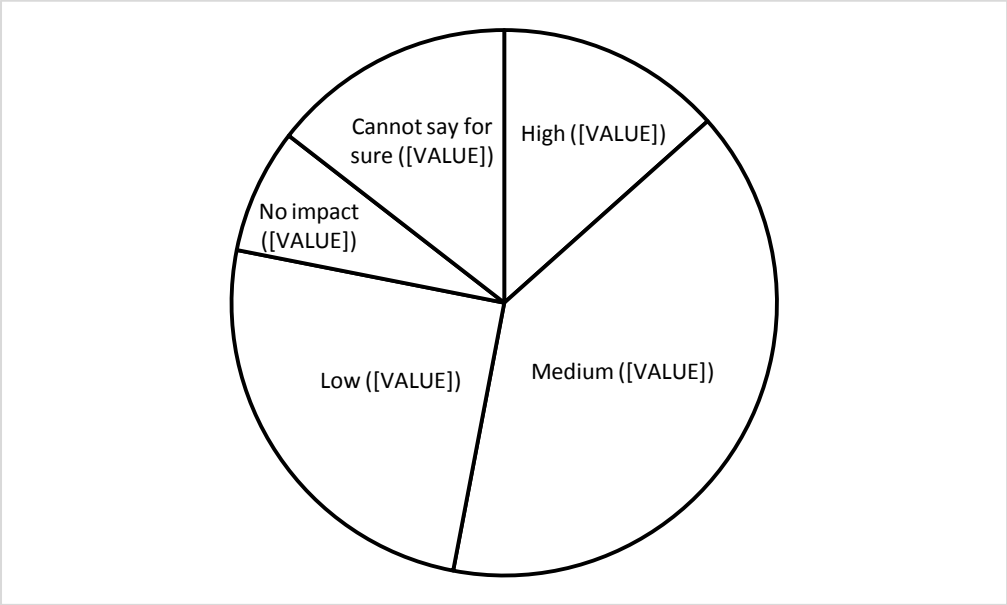

Figure 3: Description of soot's impact on residents' health

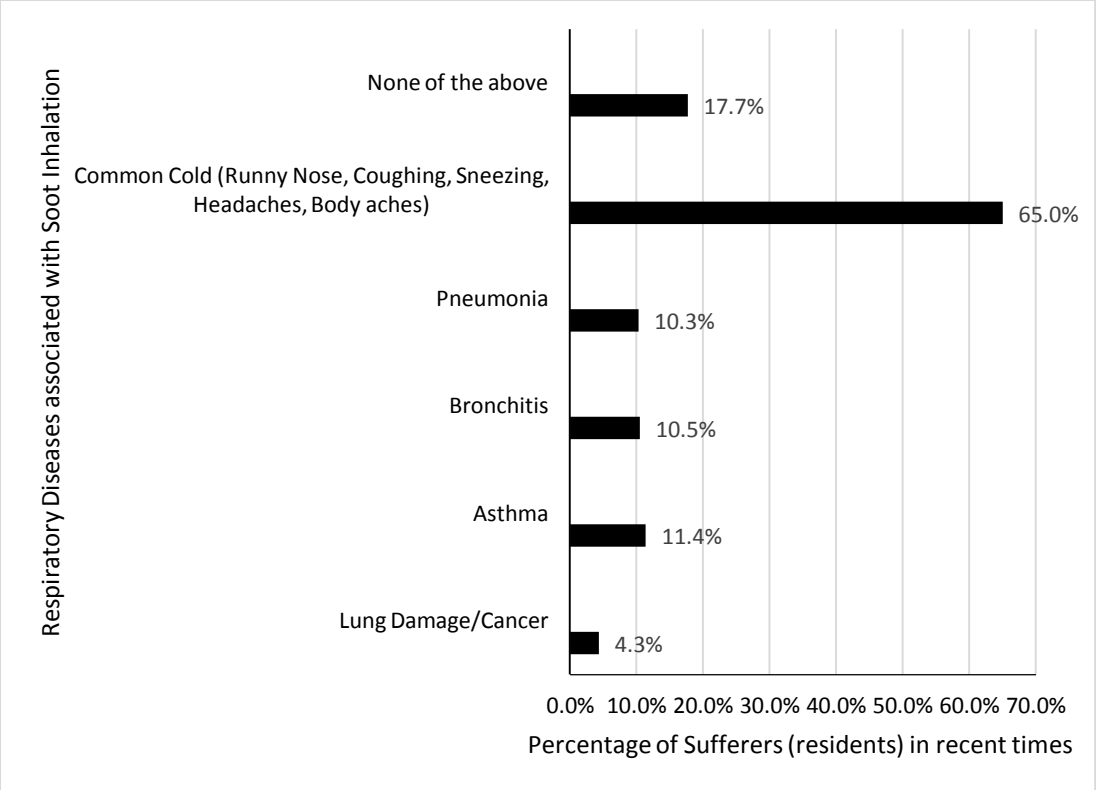

Figure 4: Respiratory diseases suffered by residents in recent times (2016-2020)

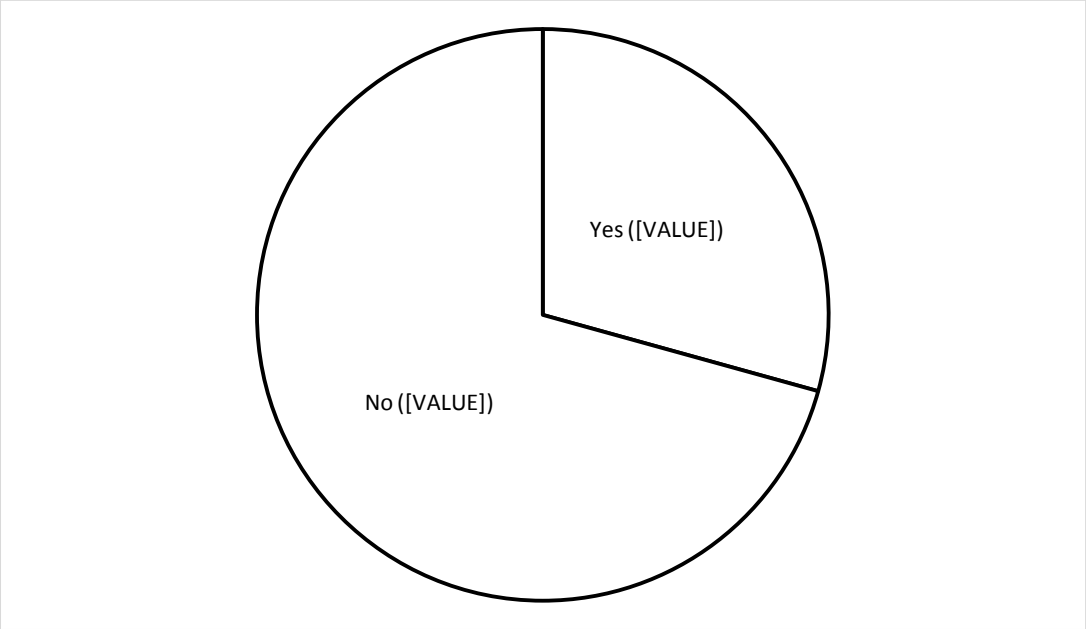

Figure 5: Response to whether premature mortality had been heard of in recent times

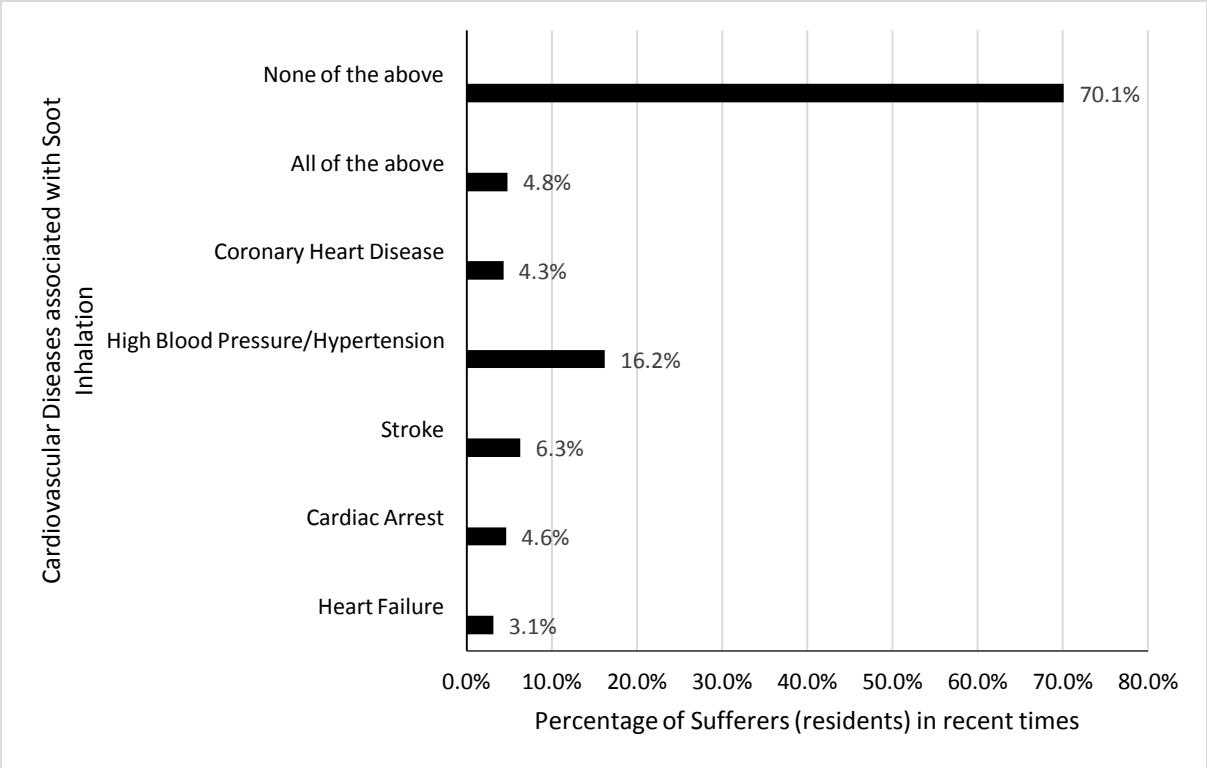

Figure 6: Cardiovascular diseases experienced by residents in recent times (2016-2020)

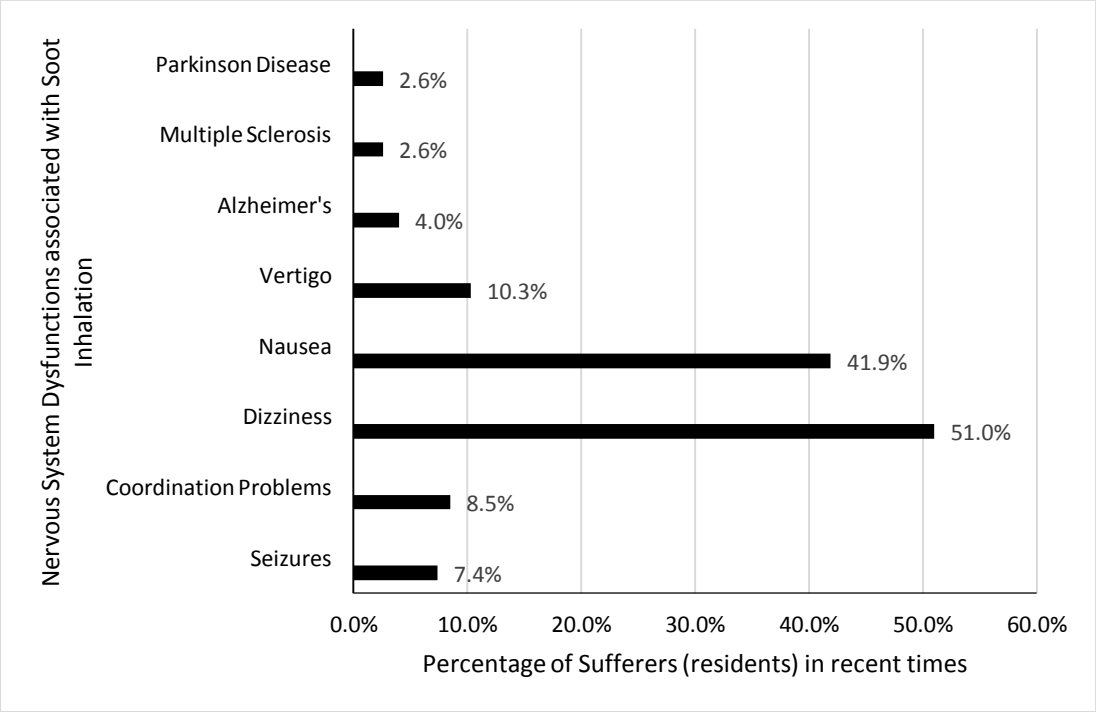

Figure 7: Adverse nervous system effects suffered in recent times

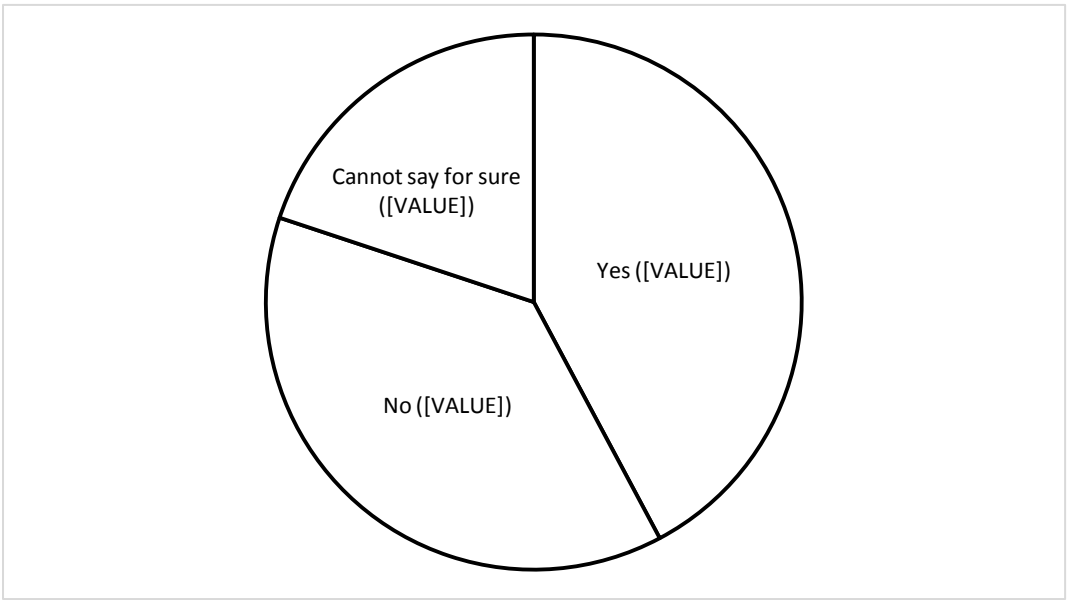

Figure 8: Response to whether residents' health had deteriorated comparing years before and after 2016

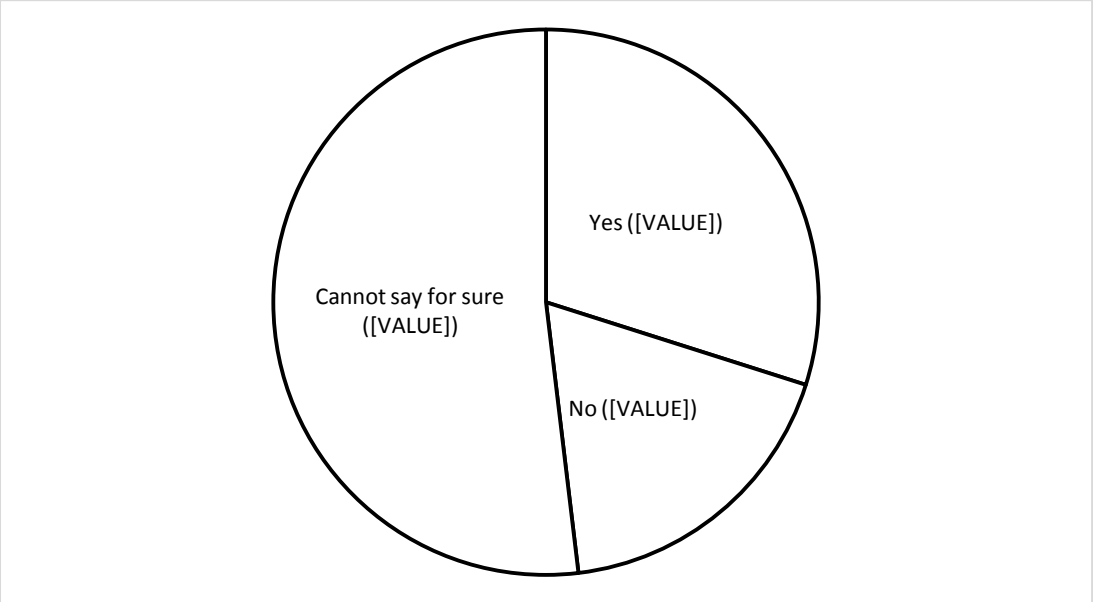

Figure 9: Response to whether deteriorating health could be attributed to the black soot

IV. Conclusion

This study assessed the impacts of the black soot in the atmosphere on public health of residents in Woji Community. The concentrations of heavy metals, polyaromatic hydrocarbons (PAH) and total petroleum hydrocarbons (TPH) in soot particles in the atmosphere of the study area were higher than those of the control area and the permissible limits. Predominant complaints/symptoms of residents in the study area included severe catarrh, nasal congestion, frequent cough, chest pain, difficulty in breathing, fever, headaches, etc. In addition, the frequency/number of cases of cardiovascular diseases, nervous system dysfunctions and respiratory diseases especially respiratory tract infections have increased after 2016 compared to the years before 2016. In recent times, residents have perceived a deterioration in their health. Common cold (runny nose, coughing, sneezing, head and body aches), nausea and dizziness are among the various diseases being suffered from. Other widespread diseases include high blood pressure/hypertension. Thus, there is a high possibility that the increased frequencies of the mentioned diseases could be attributed to the presence of black soot in the atmosphere of the study area.

References

[1]. Agency for Toxic Substances and Disease Registry (2015a) Toxic Substances Portal – Nickel.
[2]. Agency for Toxic Substances and Disease Registry (2015b) Toxic Substances Portal - Total Petroleum Hydrocarbons (TPH).
[3]. Banzorwa, C., Lezabbey, B. and Israel, S. (2018) Charting A Path Towards A Sustainable Clean
[4]. Air In Rivers State. Clean Air Summit Report 2018.
[5]. Grahame T. J., Klemm R and Schlesinger R. B. (2014) Public health and components of particulate matter: The changing assessment of black carbon, Journal of the Air & Waste Management Association, 64(6): 620-660.
[6]. Highwood, E.J. and Kinnersley, R.P. (2006) When smoke gets in our eyes: the multiple impacts
[7]. of atmospheric black carbon on climate, air quality and health. Environ Int. 2006 May;32(4):560-566.
[8]. Kalagbor, I.A., Dibofori-Orji, A.N. and Ekpete, O.A. (2019) Exposure to Heavy Metals in Soot
[9]. Samples and Cancer Risk Assessment in Port Harcourt, Nigeria. J Health Pollut. 2019 Nov 27;9(24):191211.
[10]. National Institute for Occupational Safety and Health, (2018) Lead. Information for Workers. Health Problems caused by Lead. Centers for Disease Control and Prevention.
[11]. Occupational Safety and Health Administration. (2020) Cadmium. Health Effects. United States Department of Labor.
[12]. Ogele, E.P. and Egobueze, A. (2020) The Artisanal Refining and Socioeconomic Development in Rivers State, Nigeria, 2007-2017. International Journal of Research and Innovation in Social Science, IV(IV): 2454–6186.
[13]. Srinivasarao, R., and Muralikrishna, K.V.S.G. (2014) Simulation Study to Minimize Soot and Unburnt Hydro Carbons from Steam Assisted Flares and Health Effects of Soot. International Journal of Science and Research, 3(10): 1501-1506.
[14]. Stakeholder Democracy Network. (2020) Communities not Criminals – Illegal Oil Refining in the Niger Delta. Communities not Criminals Report.
[15]. Stephen, O. (2020) Explainer: why government's move to regularise artisanal refining raises more questions than answers. Business Day (Nigeria), 16th June 2020.
[16]. Weidman, J. and Marshall, S. (2012) Soot Pollution 101: What You Need to Know and How to
[17]. Prevent it. Tackling Climate Change and Environmental Injustice. Energy and Environment. Center for American Progress.

Christopher Obi Obi, et. al. "Impact of Black Soot on Public Health of Residents in Woji Community of Rivers State." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 16(02), (2022): pp 01-11.