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Research Article

The Effects of Carbon Black on Human Health in Ubeji, Shaguolo and Environs, Delta State, Nigeria

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Abstract:

This study presents the results of a systematic review of evidence of the health effects of black carbon in Shaguolo, Ubeji and environs in Warri, Delta State. This work examined the health effects of combustion related air pollution indicated by black carbon. In this study a direct method was applied in observing the relative concentration between different locations providing an integrated time weighted average exposure. The study is based on the existing epidemiological literature to quantitatively estimate the current health effects attributed to carbon black exposure in the study area. Short-term epidemiological studies provide sufficient evidence of an association of daily variations in black carbon (BC) concentrations with short-term changes in health (all-cause and cardiovascular mortality, and cardiopulmonary hospital admissions). Cohort studies provide sufficient evidence of associations of all cause and cardiopulmonary mortality with long-term average black carbon (BC) exposure. Studies of short-term health effects suggest that black carbon (BC) is a better indicator of harmful particulate substances from combustion sources (especially traffic) than undifferentiated particulate matter (PM) mass, but the evidence for the relative strength of association from long-term studies is inconclusive. The review of the results of all available toxicological studies suggested that back carbon (BC) may not be a major toxic component of fine particulate matter (PM), but it may operate as a universal carrier of a wide variety of chemicals of varying toxicity to the lungs, the body's major defense cells and possibly the systemic blood circulation. The study examines the health outcome in relation to increase in exposure to carbon black. Based on the findings recommendations were proffered.

Keywords: Carbon black; health; human; effects; environs; cardiovascular & cardiopulmonary.

Introduction

The health effects of combustion-related air pollution indicated by black particles were identified decades ago, when the monitoring of black smoke (or "British smoke" - BS) was a widespread method for air quality assessment in Europe. The evidence about the health effects of this pollution was used to recommend the first guidelines for exposure limits (then) consistent with the protection of public health (WHO, 1979). In the 1990s, British Smoke (BS) was one of the indicators of air quality used, for example, in European time-series studies linking mortality with pollution (Katsouyanni, 2001). A recognition of the difficulties in standardizing BS measurements and an appreciation of the health effects of the non-black components of particulate matter (PM) attracted the attention of researchers and regulators to the mass concentration of inhalable or respirable fractions of suspended Particulate Matter (PM) such as Particulate Matter (PM10) and Particulate Matter (PM2.5) (WHO Regional Office for Europe, 2000). BS is not addressed by air quality regulations and the intensity of BS monitoring has decreased (Atubi, 2016).

New scientific evidence has led to a recognition of the significant role of black particles (black carbon-BC) as one of the short-lived climate change. Measures focused on Black Carbon (BC) and methane is expected to achieve a significant short-term reduction in global warming. If they were to be implemented immediately, together with measures to reduce CO_2 emissions, the chances of keeping the earth's temperature increase to less than 2°C relative to pre-industrial levels would be greatly improved (UNEP, 2011). The same measures would also directly benefit global health and food security (Atubi, 2015c).

There is still no systematic comparison of health effects estimated using Particulate Matter (PM) versus Black Carbon (BC) indicators. A World Health Organization working group has acknowledged that the evidence on the hazardous nature of combustion-related Particulate Matters (PM) (from both mobile and stationary sources) was more consistent than that for Particulate Matter (PM) from other sources (WHO Regional Office for Europe, 2007). Grahame & Schlesinger (2010) reviewed the evidence of the effects of Black Carbon (BC) on cardiovascular health endpoints and concluded that it may be desirable to promulgate a Black Carbon (BC) Particulate Matter (PM2.5) standard.

There are several types of measurement methods and commercial instruments available for continuous, semi-continuous and integrated filter sample-based optical and thermal-optical measurements of aerosol parameters reflecting combustion-derived char, soot, black carbon or elemental carbon contents in Particulate Matters (PM). The concentrations of these carbonaceous materials are low or moderate (close to source) in atmospheric Particulate Matter, and much higher in emissions from common combustion sources (diesel engines, power plants or ship engines using heavy oil, or small residential heaters using wood or other biomass). Shaguolo and Ubeji being located around Warri Refinery and Petrochemical Company are mostly affected by carbon black emissions.

Chemically Black Carbon (BC) is a component of fume particulates matter (Pm≤ 2.5 µm in aero dynamic diameter). Black carbon consists of pure carbon in several linked forms. It is formed through the incomplete combustion of fossil, fuels, bio-fuel and biomass and is emitted in both anthropogenic and naturally occurring soot. Black Carbon (BC) causes human morbidity and premature mortality.

Health risks are involved as a result of the breathing in of particulate matter (composed of black carbon, surface, nitrates, ammonia sodium chloride, mineral dust and water) measuring up to10microns or less in diameter (PM10). These particles then find their way deep into lungs and the blood streams, consequently resulting to cardiovascular and respiratory disease and eventually premature death (Atubi, 2011e).

Black carbon like all particles in the atmosphere, also affects the reflectivity, stability and duration of clouds as alters, precipitations. The effects are varied depending on the amount of soot. If it absorbs heat at the level where clouds are forming, they will evaporate. When it lies above lower stratocumulus, clouds that block the sun, it stabilizes them thereby creating cooling effect.

About 75 percent of black carbon emissions within the study area are mainly from Warri Refinery and Petrochemical Company while 25 percent is from cooking stoves which generally affects the health of women and girls. The situation is no different for children and young adults, with the high incidence of asthmatic attacks and other respiratory related disease which is also linked to the elderly.

Various studies have been carried out to show correlation between the effects of carbon black emission and health effect. Some have shown positive correlation while others show negative correlation.

Christer (2011), exposure to black carbon is linked to health impacts such as cardiopulmonary morbidity and mortality and reducing people exposure to particles containing black carbon will therefore also reduce such adverse health impacts, according to a recent report published by the World Health Organization (2011).

Due to the location of these sources, the spatial variation of Black Carbon (BC) in ambient air is greater than that of Particulate Matter (PM2.5), but in general ambient measurements or model estimates of Black Carbon (BC) are said to reflect personal exposures reasonably well and with similar precision as for Particulate Matter (PM2.5).

The main concern about exposure to carbon black is the ultrafine size of the primary particle (10-500nm) and their aggregates (80-80nm) although no research has been undertaken to evaluate the size distribution of the agglomerates found in occupational environments.

Carbon black is carcinogenic to humans based on sufficient evidence in experimental animals and inadequate evidence from epidemiological studies. Carbon black is a powerful form of elemental carbon manufactured by the controlled vapour phase hydrolysis of hydrocarbons. Different types of carbon black have a mild range of particle sizes, surfaces areas per unit mass and contents of toluene-extractable materials. Carbon black is variously known as acetylene black, chemical black, channel black, furnace black, lamp black or thermal black depending on the specific process by which it is manufactured.

Soraham and Harrington (2007) & Atubi, (2015e) based on serial rates for the general population of England and Wales as well as Nigeria significantly elevated mortality was observed for lung cancer. They concluded that carbon black or chemicals associated with the production of carbon black may have had an effect on late stages of lung cancer.

Morefeld and McCunney (2009) re-analyzed data from the German cohort but found no evidence of lung cancer declining among workers with period since leaving employment suggesting lugged exposure being related to lung cancer risk.

Recent findings have strengthened the association between inflammation and cancer (Hussain and Harris 2007, Calin and Croce, 2006) and between the particle surface area dose of carbon black and other poorly soluble low toxicity (Pslt) particles and the pulmonary inflammation.

Although studies in human have not shown a direct link between inhaled poorly soluble low toxicity (Pslt) and lung cancer many steps in the mechanism observed in rats have also been observed in humans who works in deity jobs, including increased particles lung retention and pulmonary inflammation in workers exposed to carbon black Soraham and Harrington (2007).

Only a few studies have evaluated longitudinal relationships between daily ambient and personal Black Carbon Particulate concentrations. Considering the large proportion of the 24-hour cycle typically spent in the home, the observation of a high correlation between repeated daily measurements of personal Black Carbon Particulates and Black Carbon Particulate indoors (indoor Black Carbon Particulate) (median Pearson's r>0.9 for individual regression results) is not surprising (Janssen, 2011). One study linking ambient Black Carbon Particulates with indoor Black Carbon Particulate.

Janssen, (2011) In European studies, the Ambient (ABS) of Particulate Matter (PM2.5) filters has been used as a measure of Black Carbon Particulate Ambient. ABS was found to be more strongly associated with respective personal and indoor levels than Particulate Matter (PM2.5) in these studies. It is noteworthy that indoor Elemental Carbon was reasonably correlated with indoor Abs (R=0.57-0.85) in the Dutch-Finnish study, but the slope was different for homes with and without environmental tobacco smoke. In the studies included in this report, Abs has been measured from Particulate Matter (PM2.5) filters, and thus size-fraction is not mentioned any more. Particulate Matter (PM2.5) Abs has been reported as capturing most of the particulate Abs in ambient air (Cyrys, 2003).

Adams, (2002), Short-term Black Carbon Particulate exposures are noticeably elevated during commuting and the differences between background concentrations and concentrations measured in traffic by cyclists and passengers in vehicles seem to be even greater for Black Carbon Particulate than for Particulate Matter (PM2.5).

Zuurbier, (2010) long-term epidemiological studies, contrasts in long-term exposures between persons are used. Consequently, the aim of exposure assessment is to accurately predict spatial variability in outdoor concentrations and further in personal exposures.

Hoek, 2002; Janssen, (2008), For Black Carbon Particulate (BCP), within-city variability in concentrations is larger than for Particulate Matter (PMZ5) owing to the considerable effect of local combustion sources, especially traffic, on concentrations The Black Carbon Particulate (BCP) concentration is higher in Ubeji and Shaguolo due to its close location to Warri Refinery and Petrochemical Company Carbon Black Plant.

Within-city variability may exceed between-city variability, which underlines low epidemiological studies on the long-term effects of Black Carbon Particulate (BCP) which have relied on a crude estimation of exposure: Black Carbon Particulate (BCP) concentrations measured at a single outdoor monitoring site have been assumed to reflect exposure within a city or even over a whole county. In others, the monitoring network has been dense enough to allow interpolation of exposures over an urban area. Neither method is able to sufficiently take into account small-scale variations in Black Carbon Particulate (BCP) concentrations, which may lead to an underestimation of the effects of BCP. In contrast, land-use regression models have not been used. However, many studies are available to judge spatial correlations between long-term PM2.5 and Black Carbon Particulate (BCP). Vehicular traffic, especially diesel-powered, is a major source of BCP in urban areas and this is clearly seen in Shaguolo and Ubeji as well as the Warri Refinery Petrochemical Company junction.

However, in some areas residential burning of wood or coal, and at least periodically open biomass burning may be even more important sources of Black Carbon Particulate (BCP). More locally, harbors and industrial facilities may have a pronounced effect on Black Carbon Particulate (BCP) concentrations. Altogether, when interpreting effect estimates for Black Carbon Particulate (BCP) in epidemiological studies, information on the main sources of Black Carbon Particulate (BCP) in the area should be used within-city variability which is clearly greater for long-term outdoor Black Carbon Particulate (BCP) than for Particulate Matter (PM2.5), which is a challenge for exposure assessment in epidemiological studies on the long-term effects of air pollution. A high proportion of spatial variation in ambient Black Carbon Particulate (BCP) can, however, be explained with the use of land-use regression models with carefully selected predictors. In the few available studies including both Black Carbon Particulate (BCP) and Particulate Matter (PM2.5), the performance of the model has typically been at least as good for Black Carbon Particulate (BCP) and for Particulate Matter (PM2.5).

Barregard (2008), experimental Black Carbon (BC) is an indicator of combustion-related air pollution and was recently recognized as one of the short-lived climate-forcers. This report presents the results of a systematic review of evidence of the health effects of Black Carbon (BC) in ambient air. It concludes that epidemiological studies provide sufficient evidence of the association between cardiopulmonary morbidity and mortality with Black Carbon (BC) exposure. The review of the toxicological studies suggested that BC may not be a major directly toxic component of fine Particulate Matter (PM2.5), but it may operate as a universal carrier of a wide variety of chemicals of varying toxicity to the human body. A reduction in exposure to Particulate Matter (PM2.5) containing Black Carbon (BC) and other combustion-related particulate material for which Black Carbon (BC) is an indirect indicator should lead to a reduction in the health effects associated with PM and simultaneously contribute to the mitigation of climate change.

Chen Allan (2015) aerosol particles can affect the radiation balance leading to a cooling or heating effect with the magnitude and sign of the temperature change largely dependent on aerosol optical properties, aerosol concentrations, and the albedo of the underlying surface. A purely scattering aerosol will reflect energy that would normally be absorbed by the earth-atmosphere system back to space and leads to a cooling effect. As one adds an absorbing component to the aerosol, it can lead to a heating of the earth-atmosphere system if the reflectivity of the underlying surface is sufficiently high.

According to Chen Allan (2015), up to 30% of the total carbon stored in soils is contributed by black carbon. Especially for tropical soils black carbon serves as a reservoir for nutrients showed that soils without high amounts of black carbon are significantly less fertile than soil that contain black carbon. An example for this increased soil fertility is the Terra Preta soils of central Amazonia, which are presumably human made by pre-Columbian native populations. Terra Preta soils have on average three times higher soil organic matter (SOM) content, higher nutrient levels and a better nutrient retention capacity than surrounding infertile soils. In this context, the slash and burn agricultural practice used in tropical region does not only enhance productivity by releasing nutrients from the burned vegetation but also by adding black carbon to the soil.

Anderson (2001), particulate matter is the most harmful to public of all air pollution in Europe. Black carbon particulate matter contains very fine carcinogens and is therefore particularly harmful. It is estimated that some 640,000 premature human deaths could be prevented every year by utilizing available mitigation measures to reduce black carbon in the atmosphere.

Humans are exposed to black carbon by inhalation of air in the immediate vicinity of local source. Important indoor sources include candles and biomass burning whereas traffic and occasionally forest fires are the major outdoor which decrease sharply with increasing distance from (traffic) sources which makes it a typical component of particulate matter. This makes it difficult to estimate exposure of population. For particulate matter epidemiological studies have traditionally relied on single fixed site measurements or inferred residential concentrations. Recent studies have shown that as much black carbon is inhaled in traffic and at other locations. High peak concentrations are encountered during car driving. High vehicle concentration of black carbon have been associated with driving during rush hours, on highways and in dense traffic. Even relatively low exposure concentrations of black carbon have an inflammatory effect on the respiratory system of children.

The public health benefits or reduction in the amount of soot and other particulate matter has been recognized for years. However, high concentrations persist in industrialized areas in Asia and in urban areas in the West such as Chicago. The WHO estimates that air pollution causes nearly two million premature deaths per year. By reducing black carbon, a primary component of fine particulate matter, the health risks from air pollution will decline. In fact, public health concerns have given rise to many efforts to reduce such emissions, for example, diesel vehicles and cooking stoves.

Although case reports have limited value in occupation health, they can be used to highlight unusual occurrences. A report in 2012 described "a 44 – year – old man who had intense exposure to carborn black." A week thereafter, he developed shortness of breath and cough. Pulmonary function test revealed a mild obstruction. "The patient responded to treatment with fluticasone and salmeterol with a reduction in symptoms and improvement in his spirometry to a normal range." (Halemariam,et al., 2012) The authors concluded: "acute exposure to carbon black can cause respiratory symptoms and an obstructive ventilator defect."

Given black carbon's relatively short lifespan, reducing black carbon emissions would reduce warming within weeks. Because black carbon remains in the atmosphere only for a few weeks, reducing black carbon emission may be the fastest means of showing climate change in the near term. Control of black carbon, particularly from fossil-fuel and bio-fuel sources, is very likely to be the fasted method of showing global warming in the immediate future, and major cuts in black carbon emissions could slow the effects of climate change for a decade or two. Reducing black carbon emissions could help keep the climate system from passing the tipping points for abrupt climate changes, including significant sea-level rise from the melting of Greenland and/or Antarctic ice sheet. Emissions of black carbon are the second strongest contribution to current global warming, after carbon-dioxide emission.

The vast majority of controlled human exposure studies set up to identify adverse responses took diesel engines as a source for Black Carbon (BC) emissions. These studies were limited in the duration of exposure, which did not usually last much longer than a single two-hour period. The studies used Particulate Matters (PM) exposure concentrations in the range 100-350 pg/m3. Effects related with carbonaceous emissions included oxidative stress, inflammation, lipid peroxidation and atherosclerosis, change in heart rate variability, arrhythmias, ST-segment depression (heart function), and changes in vascular function (such as blood pressure) (Grahame and Schlesinger, 2010).

For this research, studies were selected that evaluated particulate matter (PM) mixtures relevant for the questions, mainly diesel engine exhaust, wood-smoke and concentrated ambient particulate matter (PM2.5). Controlled exposure Health effects of black carbon studies compared health responses to the selected exposure with those to filtered air in order to adjust for potential effects of the experimental setup. Usually, each subject served as his/her own control. Typically, the evaluated particulate matter (PM) exposures (100350 μg/m3) were higher than those encountered in ambient air, although not excessively so. Because of ethical concerns, healthy subjects or subjects with mild disease were commonly selected for the controlled exposure studies that focused only on mild, reversible adverse effects.

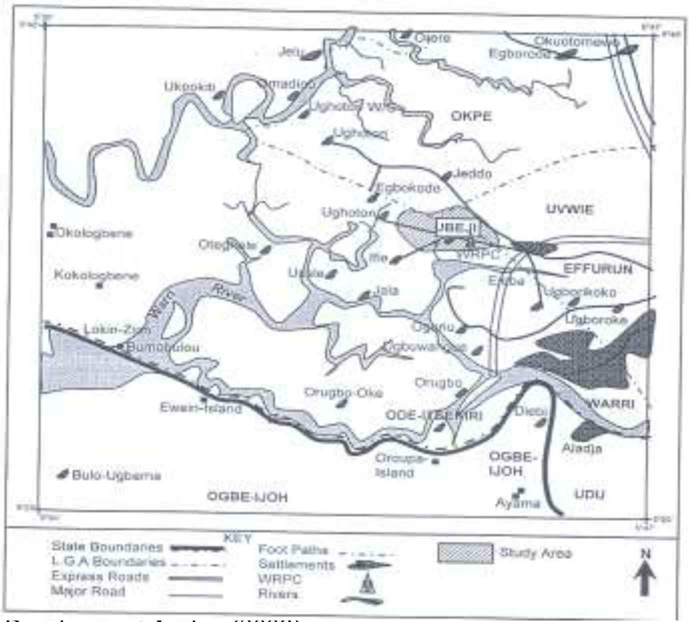
Study Area

Ubeji is located in Delta State Nigeria and it is next to Kalorugbene creek Ubeji is nearby to Odi, Ifie, Ajatitor, Ugbokodo and Benji. Ubeji is located on latitude 5^0 34', north and longitude 5^0 42' east. It is situated on the average elevation of 9 meters (30feets) above sea level. It is about 4km east from Ekpan. Ubeji is moderately populated.

Shaguolo is a close cum street adjacent to Warri Refinery bounded by Ubeji and Ekpan is located around latitude $5^0$31'N and $6^0$11N and longitude $5^0$44E and 5^0 47E. The total areas of study are approximately over 200 square kilometers and are close to each other.

The relief is low intercepted with streams and the area is poorly drained. It is located in the mangrove swamp forest of Nigeria which is intermixed with a little of the rain forest and this accounts for the presence of evergreen trees.

Fig: 1: Map of Delta State Showing Study Area
Source: *Modified after Ministry of Lands, Survey and Urban*



Development Asaba, (2008)

Fig. 2: Map of Warri South Showing Study Area

Source: *Modified after Ministry of Lands, Survey and Urban Development Asaba, (2008)*

Research Methodology

The simple random sampling was used; reconnaissance visit was made to the study area for proper evaluation of the health of residents who were exposed to carbon black over a period of time. The vast majority of controlled human exposure studies set up to identify adverse response took ambient air, diesel and pure elemental carbon as a source of black carbon emissions. These studies were limited in the duration of the exposure, which did not usually last much longer than a single two-hour period. The studies used Particulate Matter exposure concentrations in the range 100-350 μg/m3. Effects related to carbonaceous emissions included oxidative stress, inflammation, lipid peroxidation and atherosclerosis, change in heart rate variability, arrhythmias, ST-segment depression (heart function), and changes in vascular function (such as blood pressure) (Grahame & Schlesinger,2010)

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Data were collected from two major sources. They are primary and secondary sources. The method used in this study include data collection which comprised of mainly field observation using spirometer and photometer to assess the mass concentration and toxicity of particulate matter being inhaled and its health outcome and secondary data from hospital record showing the number of patients admitted over a certain period of time as a result of respiratory and cardiovascular related diseases.

Using the base map obtained from the Town Planning Authority of the Warri South Local Government Area. Time profile exposure to carbon black within the area was studied using a portable photometer which has been designed for intrinsic safety.

An independent control source was established at Ubeji, Shaguolo, and A-close since a small amount of specific aerosol in the presence of a large amount of interfering dust is not feasible with a photometer. The control sample served as a standard within Ubeji, Shaguolo and environs. In this study, spirometry and inhalation challenge test were used for lung function testing. In all, 600 examinations were performed among people exposed at Warri Refinery and Petrochemical Company carbon plant, Shaguolo, Ubeji and environs.

In this work, a simple random sampling was used. The data for this research was taken from location within the study area, with a study population of 935 persons within Warri Refinery and Petrochemical Company Plant area, Ubeji, Shaguolo and environs.

The sampling population A is 374, Location B is 187, Location C is 140, Location D is 140 and Location E is 94 were drawn separately assessing the respiratory health of the residents within the area.

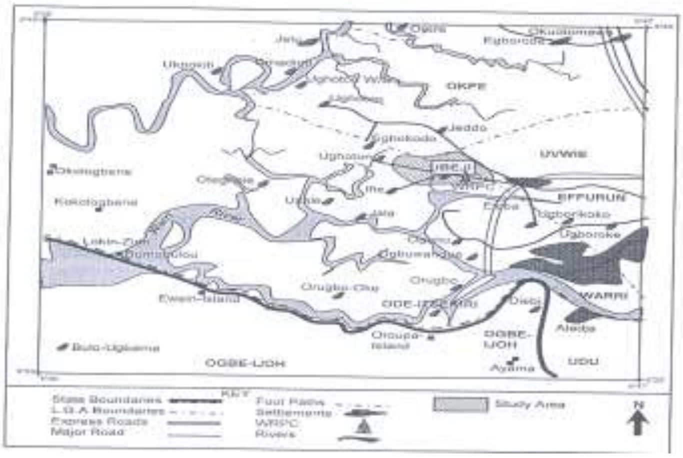

Fig. 3: Map of Warri South Showing the Sampling Population Locations within the Study Area

Source: *Modified after Ministry of Lands, Survey and Urban Development Asaba, (2008)*

The method applied in this study was a direct one, observing relative concentrations between different locations providing an integrated time weighted average exposure. In addition, workers can be aware of aerosols concentrations while carrying out his tasks so that he can modify work practice to reduce exposure. The study is based on the existing epidemiological literature to quantitatively estimate the current health effects attributed to carbon black exposure in the study area (within a resident of more than 2000 but of a sample population of 935 people was used) using Particulate Matter (PM10) as indicator of urban air quality and a proxy for concurrent exposures to different pollutants.

Four methods of data analysis were adopted in this study.

i. The Epidemiological Study
ii. Time Series Study
iii. Cross-Sectional and Cohort
iv. Dose Response Functions

Discussion of Findings/Results

Since different measures of PM are used in the literature, published estimates of relative risks were converted to PM10 equivalent estimates. It was assumed that PM10 = 0.55 of total suspended particles or TSP, that PM2.5=0.5 of PM10, and that PM10 equals PM13 or PM15. Analysis of the size distribution of PM suggest that there are not many particles, by weight, between PM10 and PM15.

Table 1: Summary of relative risks estimated by the present study for the health outcomes

Cause	Central Estimate	LL 95%	UL 95%	Notes
Mortality	1.026	1.009	1.043	Adults age 30+
Hospital admission for CVD causes	1.009	1.006	1.013	
Hospital admission for respiratory disease	1.016	1.013	1.020	
Acute bronchitis	1.306	1.135	1.502	Children < 15
Asthma exacerbation	1.051	1.047	1.055	Children< 15
Asthma exacerbation	1.004	1.000	1.080	Adult<15+
RAD	1.094	1.079	1.109	Adult 20+
Occurrence of respiratory symptoms	1.07	1.02	1.11	

Source: Field Work, (2017)

Table 1 shows the health endpoint considered and summarizes the dose response function used in this report, however, potential mortality impacts on children were not included in the present estimate. Several cross-sectional studies have reported association between PM concentrations and neo-natal and infant mortality (Penna and Duchiade, 1996). There is also extensive evidence to indicate that short-term changes in PM affect hospital admissions for respiratory diseases.

Table 2: Annual mean concentration of PM2.5 from 2016-2017

Location	Mean Concentration $\mu g/m^3$
WRPC Plant 1	53.8
Ubeji	51.2
Shaguolo	47.4
A Close	46.1
WRPC Plant 2	52.1
Ubeji A	51.2
Shaguolo A	46.5
A Close A	44.5

Source: Field Work, (2017)

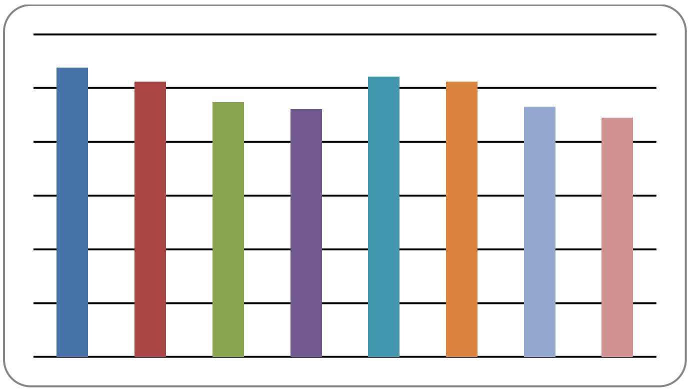

Fig 4: Bar Chart Showing Annual Mean Concentration PM2.5 2016-2017

Using the controlling ambient standards recently promulgated by the U.S. Environmental Protection Agency (1996) for Particulate Matter (PM2.5), the annual average standard for Particulate Matter (PM2.5) is $15\mu g/m^3$. Assuming a ratio between Particulate Matter (PM2.5) and Particulate Matter (PM10) – approximately 0.5 (U.S EPA, 1996) – this would be equivalent to $30\mu g/m^3$ Particulate Matter (PM10). To estimate the attributable health effects from air pollution exposure, the change from these three presumed effect levels to the existing ambient concentrations in each city was calculated, based on current monitoring information.

It should be stressed; however, that all impact estimates calculated using these standards understate the overall health burden associated to exposure to Particulate Matter (PM10) in urban areas. As no threshold seems to exist, health effects are likely to occur down to the background level of approximately $7\ \mu g/m^3$ of Particulate Matter (PM10) (U.S. EPA 1996).

For each of the included health endpoints, a relative risk estimate (RR) was determined pooling the estimates from the available studies, as discussed above. The relative risk is the increase in the probability of a given health effect associated with a given increase in exposure (usually $10\mu g/m^3$ in epidemiological studies of PM).

The attributable proportion (A) of health effects from air pollution for the entire population can be calculated as:

$$A = (RR - 1)\ RR \text{ - - - - - - - - - equation (1)}$$

To calculate the number of cases attributable to air pollution (E), the following formulation was used:

$$E = A^* B^*C^*P \text{ - - - - - - - - - equation (2)}$$

Where:

B = Population baseline rate of the given health effect

C = Relevant change in air pollution

P = Relevant exposed population for health effect

Bo is obtained from available health statistics, C is obtained from monitoring networks in each city, and P is obtained from census data for the cities under study.

Following Kunzil, et al., (1999), the population baseline rate is the proportion of the exposed population that would experience the health outcome assuming a baseline level (of no effect level) of air pollution. This can be calculated as:

B = Bo/[1 + (RR-1) (C/10)]- - - - - - - - - equation (3)

Where:

Bo = Observed rate of the health effect under current exposure

B = Baseline rate of the health effect under baseline exposure

C = Relevant change in air pollution

RR = Relative risk estimate per 10 μg/m^3 determined from the pooled studies.

This number is divided by 10 to obtain the risk per unit.

Bo is obtained from available health statistics, C is obtained from monitoring networks in each city, and P is obtained from census data for the cities under study.

This formula adjusts the current prevalence or incidence level of the health effect, using the relative risk, to the level that would exist with a lower air pollution concentration. As an example of these calculations, assume that (a) the relative risk for respiratory symptoms is 1.10 for a one μg/m^3 change in Particulate Matter (PM10); (b) every person in the city is exposed to a Particulate Matter (PM10) concentration of 50 g/m^3 and the projected "standard" is 20 g/m^3; (c) people have an average of 10 symptoms per year and (d) there are million people in this city who are expected to respond to Particulate Matter (PM10) respiratory symptoms.

Using equation (3) it is possible to calculate the baseline prevalence associated with a lower air pollution level) as B – 10/(1_ (0.1) (30/10) = 7.7. The attributable risk per one g/m^3 (a) can be calculated from equation (1) as 0.09 = 0.1/1.10. Thus, for this example roughly 9% of the total number of symptoms in the population can be attributed to a one g/m^3 change in PM10. Applying these estimates to equation (2), the numbers of cases attributable to air pollution are:

E = (0.09) * (7.7) * (30) * 1,000,000) = 20.7 million extra days with symptoms due to air pollution.

Table 3: **Hospital Admission Record over a period of time based on carbon black effect on Human Zonal Clinic**

Year	**No.of Children**	**Women/ Girls**	**Adult**	**Young Adult**	**Elderly**
2014	210	100	50	150	40
2015	791	70	70	600	50
2016	2010	300	110	700	85
2017	734	80	60	55	500

Source: Field Work, (2017)

From the hospital record, the researchers observed that different numbers of people were admitted as a result of asthma and asthma related symptoms ranging from children, girls and women, and the elderly. This study revealed the association between carbon black exposure and hospital admissions for cardiovascular and respiratory diseases in the study area.

From table 3, there is a noticeable change in the number of patients being admitted in the hospital and that was as a result of no production of black carbon in the last few years in Warri Refinery and Petrochemical Company (WRPC). The groups affected are mostly children and the young adults. The admission was at its peak in 2014 when the production of black carbon was ongoing.

Most exposure to carbon black occurs when people breathe contaminated air and these types of exposure usually occur in the area of carbon black production. Carbon black particles are heavy and drop quickly out of the air, the dust is a nuisance because it is black and sticky, very difficult to wipe off stain or other objects and this is likely to cause serious health effects which led to high hospital admission within the period of its production. All the people within the whole age bracket were affected. Most patients who were admitted had a long history of carbon black exposure.

Table 4: Showing black carbon exposure in relation to human health within the study area

Carbon Black	**Number of Person**	**Health Human Conditions**	**Health Outcome**	**Notes**
Ambient Particle mater	24 24 50	Healthy Ones Asthmatic ones Healthy workers	Dry cough Consistent wheezing & cough. Decreased pulmonary function & chest pain	0-14 15+ 45+
Diesel Engine Exhaust	18 7	Healthy non smokers Healthy smokers	Respiratory disease prone to cancer and obstructive airway diseases	15-45 26-45
Elemental Carbon	16 10	Healthy boys and girls	May be susceptible bronchitis Type II diabetes & Tiredness	

Source: Field Work, (2017)

From the table 4, half of the healthy ones are affected and they are mostly children.17 persons were affected out of the 24 who were asthmatic majority being children and young adults. From all indications ambient particle matter affects children more upon exposure, healthy smoker are prone to cancer over a long term exposure to black carbon. When exposed elemental carbon healthy ones both girls and boys will be susceptible to bronchitis and other respiratory diseases. Type II diabetes is common among girls and women due to their lifestyles upon exposure to elemental carbon over a period of time.

Within the smokers group, carbon black dust exposure reveals an impact upon the lungs. Smokers also displayed a significant sign of obstructive airways disease compare to the group of non-smokers. Chronic inhalation exposure of production workers has caused decreased pulmonary function and myocardial dystrophy. There is evidence that carbon black has been responsible for induction of skin cancer in exposed workers.

Nevertheless, smokers are displaying significant more frequently signs of obstructive airway diseases compared with non-smokers. In the smokers group 7.3% of the study subjects with signs of obstructive airway disease compared with 3.96% in the group of non-smokers.

Table 5: Assessment of Smoke and Non-Smoke Health Outcome

Study Subject	Total of Subject	Health Outcome	Percentage of Impact
Smokers	474	Obstructive Airway Diseases	70
Non Smokers	169	Decreased Pulmonary Function	25
Healthy Subject	34	Bronchial hyper-responsiveness.	5.1
	677		**100**

Source: Field Work, (2017)

There is an overall percentage of 5.1% that is not higher than the subject with bronchial hyper-responsiveness. In addition to health indices of pulmonary function symptoms and fibrotic disease carbon black workforce was also evaluated for cancer which had not led to death.

Table 6: Health Outcomes Attributable to PM10 Concentration Above 30μg/m^3 2017

	Estimated proportion (%)	**95 % Confidence limits**		**Estimated number of attributable causes**
Mortality (excluding accidental causes) (age ≥ 30)	4.7	1.7	7.5	3472
Hospital admissions for respiratory dieses	3.0	2.5	3.7	1887
Hospital admissions for CVD	1.7	1.2	2.5	2710
Acute bronchitis (age < 15)	28.6	18.4	32.9	31 524
Asthma attack (age < 15)	8.7	8.1	9.2	29 730
Asthma attack (age ≤15)	0.8	0	1.5	11 360
RAD (age > 20)	14.3	12.5	15.9	2702 461
Respiratory symptoms	11.3	3.7	11.0	10 409 836

Source: Field Work, (2017)

Table 6 summarizes the result of the study in terms of health impact expressed as proportion and number of cases attributable to air pollution. Details of the findings are given as follows:

Table 7: Admission to hospital for CVD cause attributable PM 10 concentration above 30μg/m^3.

Study Area	Estimated No of Cases	95% CI		Estimated % of Cases	95% CI	
WRPC Plant I	275	185	391	2.1	1.4	3.0
WRPC Plant II	171	115	244	1.4	1.0	2.0
Ubeji	520	349	742	1.5	1.0	2.2
Ubeja A	148	99	211	1.9	1.2	2.6
Shaguolo	58	39	83	1.5	1.0	2.1
Shaguolo A	1.007	677	1.436	1.9	1.2	2.6
A close	370	249	528	1.9	1.3	2.8
A close A	163	110	233	1.3	0.8	1.8
Total	2710	1823	3869	1.7	1.2	2.5

Source: Field Work, (2017)

Air pollution is responsible for 1.7% of all hospital admissions due to cardiovascular causes in the study areas. Due to the high frequency of cardiovascular disease, the estimated number of attributable admission is 2.710.

Table 8: Admission to hospital for respiratory causes attributable to PM 10 concentration above 30μg/m^3

Study Area	Estimated No of Cases	95% CI		Estimated % of Cases	95% CI	
WRPC Plant I	243	200	300	3.6	3.0	4.5
WRPC Plant II	119	97	147	2.5	2.0	3.1

Ubeji	370	303	457	2.7	2.2	3.3
Ubeja A	107	88	132	3.2	2.6	4.0
Shaguolo	30	25	38	2.5	2.1	3.1
Shaguolo A	648	531	800	3.2	2.6	4.0
A close	257	210	317	3.4	2.8	4.1
A close A	114	93	141	2.2	1.8	2.7
Total	1887	1547	2332	3.0	2.5	3.7

Source: Field Work, (2017)

A total of 1,887 hospital admission for respiratory disease (3.0%) are estimated as attributable to air pollution in the study area.

Table 9: Cases of acute bronchitis attributable to PM 10 concentration above 30µg/m^3

Study Area	**Estimated No of Cases**	**95% CI**		**Estimated % of Cases**	**95% CI**	
WRPC Plant I	3.360	2.229	3.776	32.3	21.4	36.3
WRPC Plant II	1.682	1.046	1.982	23.2	15.7	29.7
Ubeji	3.723	2.343	4.346	26.6	16.7	31.0
Ubeja A	1.084	704	1.236	30.1	19.5	34.3
Shaguolo	974	608	1.144	25.7	16.0	30.2
Shaguolo A	10.966	7.126	12.502	30.1	19.5	34.3
A close	6.235	4.081	7073	30.8	20.2	35.0
A close A	3.500	2.140	4.180	23.3	14.3	27.9
Total	31.524	20.277	36.241	28.6	18.4	32.9

Source: Field Work, (2017)

Acute bronchitis in children was the endpoint with the highest attributable proportion reaching 32.3% in the study area. Overall 31.524 attributable cases were estimated, amounting to 28.6% of the total.

Table 10: Cases of Asthma exacerbation attributable to PM 10 concentration above 30µg/m^{3,} age 15 years

	Estimated No of Cases	**95% CI**		**Estimated % of Cases**	**95% CI**	
WRPC Plant I	3.341	1.117	3.559	10.3	9.6	11.0
WRPC Plant II	1.496	1.393	1.598	7.2	6.7	7.7
Ubeji	3.380	3.147	3.609	7.8	7.2	8.3
Ubeja A	1.039	969	.108	9.3	8.6	9.9
Shaguolo	872	812	931	7.4	6.9	7.9
Shaguolo A	10.517	9.804	11.214	9.3	8.6	9.9
A close	6.055	5.646	6.454	9.6	9.0	10.3
A close A	3.028	2.817	2.236	6.5	6.0	6.9
Total	29.730	27.705	31.709	8.7	8.1	9.2

Source: Field Work, (2017)

Table 11: Case of Asthma exacerbation attributable to PM 10 concentration above 30µg/m^{3,} age 15 years

Study Area	**Estimated No of Cases**	**95% CI**		**Estimated % of Cases**	**95% CI**	
WRPC Plant I	1.601	0	3.160	0.9	0	1.9
WRPC Plant II	774	0	1.531	0.6	0	1.3
Ubeji	1.700	0	3.363	0.7	0	1.4
Ubeja A	611	0	1.206	0.8	0	1.7
Shaguolo	468	0	925	0.7	0	1.3
Shaguolo A	4.040	0	7.981	0.8	0	1.7
A close	1.517	0	2.995	0.9	0	1.7
A close A	651	0	1.289	0.6	0	1.1
Total	11.360	0	22.451	0.8	0	1.5

Source: Field Work, (2017)

The proportion of cases of asthma exacerbation was also estimated separately for children (under 15 years old) and adults. For the former group the attributable proportion was 8.7% or 29.730 extra cases, for the older group the attributable proportion was lower (0.8%), but the number of attributable cases remained substantial.

Finally, table 10 and Table 11 show the result for the other two health outcomes considered, the number of days with restricted activity (RAD) for respiratory conditions among people more than 20 years of age and the occurrence of respiratory symptoms for all ages. A sizable proportion of both, 14.3% and 11.3% respectively are attributable to Particulate Matter (PM 10) concentration above 30μg/m$^{3.}$ These proportion represent about 3 million extra RADs and 10 millions extra episodes

Table 13: Days of restricted activity (RAD) for respiratory causes attributable to PM 10 concentration above 30μg/m^{3,} (Age 20 years)

Study Area	Estimated No of Cases	95% CI		Estimated % of Cases	95% CI	
WRPC Plant I	3788 305	331 621	419 506	16.7	14.7	18.6
WRPC Plant II	195 044	169 998	218 618	12.0	10.5	13.5
Ubeji	412 567	360 126	461 760	12.9	11.2	14.4
Ubeja A	143 067	125 396	159 494	15.2	13.3	16.9
Shaguolo	117 482	102 445	131 621	12.3	10.7	13.8
Shaguolo A	951 009	833 540	1 060 199	15.2	13.3	16.9
A close	346 780	304 235	386 243	15.7	13.8	17.5
A close A	159 206	138 482	178 798	10.9	9.5	12.2
Total	2 702 461	2 365 843	3 016 238	14.3	12.5	15.9

Source: Field Work, (2017)

Table 14: Days of restricted activity (RAD) for respiratory causes attributable to PM 10 concentration above 30μg/m^{3,} All Ages

Study Area	Estimated No of Cases	95% CI		Estimated % of Cases	95% CI	
WRPC Plant I	1 391 577	464 487	1 948 848	13.4	4.5	18.7
WRPC Plant II	691 277	223 334	989 901	9.5	3.1	13.5
Ubeji	1 514 944	492 233	2 160 776	10.1	3.3	14.5
Ubeja A	522 946	172 639	737 790	12.1	4.0	17.0
Shaguolo	415 922	134 616	594 844	9.7	3.1	13.8
Shaguolo A	3 681 317	1 215 309	5 193 734	12.1	4.0	17.0
A close	1 500 668	497 274	2 111 853	12.5	4.1	17.6
A close A	691 186	221 611	995 104	8.5	2.7	12.3
Total	10 409 836	3 421 504	14 732 851	11.3	3.7	16.0

Source: Field Work, (2017)

Time-series study design has been the most frequently used method to evaluate the acute effects of Black Carbon (BC) exposure on population health. The design is based on comparing short-term (typically daily) variations in exposure with short-term variations in population health, for example, mortality or hospitalization. In the setting, population exposure is assessed by measuring Black Carbon Particulate (BCP) at one or more centrally located outdoor monitoring stations.

Considering the large proportion of the 24-hour cycle typically spent in the home, the observation of a high correlation between repeated daily measurements of personal BCP and BCP indoors (indoor BCP) (median Pearson's >0.9 for individual regression results) is not surprising (Janssen 2008). One study linking ambient Black Carbon Particulate with indoor Black Carbon Particulate has, therefore, been included in Table 14.

Table 15: Relationship of Ambient Black Carbon Particulate (BCP) with respective Indoor and Personal Concentrations in Longitudinal Studies with repeated 24-Hour Measurements

Study Population/ Locations	Abs or EC (n)	Study Area	Relationships between:			
			Ambient Personal BC	Ambient Personal $PM_{2.5}$	Ambient Indoor BC	Ambient Indoor $_{2.5}$
82 Respiratory Disease Patient 152 Homes	463 2hours/Home	Ubeji A Shaguolo Ubeji A Shaguolo A Close Ubeji B	0.93 (0.92) 0.81 (0.62)	0.79 (0.43) 0.73 (0.45)	0.96 (0.84) 0.74 (0.49) 0.79 0.64 0.92 0.90	0.84 (0.47) 0.00 (0.51) 0.70 0.40 0.80 0.55
15 Senior Adults 25 Homes		Ubeji A Shaguolo	0.08 (0.33) 0.44 (0.70)	0.60 (0.73) 0.47 (0.63)		

		Ubeji A Shaguolo	0.30 (0.60) 0.41 (0.08)	0.17 (0.37) 0.55 (0.75)	0.30 (0.91) 0.05 (0.29)	0.17 (0.29) 0.55 (0.89)
38 Women/Girls (Asthmatic Patients)	Abs (162)	Ubeji A	0.69 (0.67)	0.14 (0.04)		

Source: Field Work, (2017)

The study found high levels of Particulate Matter (PM) concentration across all suburbs. The observed high levels of Particulate Matter (PM) concentration could be attributed to the vehicle exhaust emission and re-suspension of road dust attributed to vehicle movements and the close proximity of respondents' homes to the roads. This further explains the high Particulate Matter (PM) concentration levels, across all suburbs, which were above the international recommended limits for residential areas. Other sources of observed high Particulate Matter (PM) levels could be attributed to anthropogenic activities of which its description is beyond the scope of this project.

Moreover, the observed high Particulate Matter (PM) levels might explain the high prevalence or cough, breathlessness as well as asthma, although no statistically significant association was observed. The observed high prevalence of asthma and to a certain extent bronchitis symptoms is in upkeep with findings of earlier studies.

The study found high prevalence levels of cough, breathlessness, and asthma of which none were found to be associated with either the Particulate Matter (PM) concentration or residence location. This is different from the results of previous studies which suggested that PM concentration was generally associated with acute and to a certain extent, long term poor pulmonary related health outcomes, which was not associated with location, but only Particulate Matter (PM) concentration being present across all suburbs. The health effects attributed to Particulate Matter (PM) exposure among Ubeji, Shaguolo and environs residents might be influenced by individual characteristics such as gender, age, socio-economic status, and health status and the effect might be further aggravated by time spent outdoors by individuals. Among all of the assessed respiratory disorders, only an episode of phlegm and cough was found to be associated with Particulate Matter (PM) concentration, while the cough symptom was observed to be associated with the type of energy used for cooking, as long as one resides in Ubeji, Shaguolo and environs. This could be explained by the observed high PM concentration levels across all suburbs, which could be further attributed to resident's movement across the city as well as indoor related exposure to biomass fuel and environmental tobacco exposure. Similarly, the observed association between Particulate Matter (PM) and an episode of phlegm and cough supports earlier findings by earlier studies which associated episodic respiratory symptoms such as cough to Particulate Matter (PM) concentration.

The study found that Ubeji, Shaguolo and environs residents' risk for poor respiratory health outcomes is multifactorial and may include factors such as environmental exposure to poor indoor air quality both at home and at the work place. Furthermore, other studies reported a synergistic impaired effect between occupational exposure to dust or chemical pollutants and smoking on individual's lungs, while smoking alone is proven to affect the lungs which contribute to the reduction of lung functional capacity and risk for poor respiratory health. Similarly, an individual's age is proven to increase his/her vulnerability to poor respiratory health outcomes mainly due to a weakened immune system and poor lung function, which render individuals to be susceptible to developing respiratory related symptoms and illness. Thus, the effect of other factors such as smoking, occupational exposure and personal exposure to indoor pollutants needs to be quantified for the study area population to establish the overall country burden of respiratory diseases due to both indoor and outdoor pollutants.

Table 16: Assessment of the Respiratory Health of Carbon Black Workers in Ubeji, Shaguolo and its Environs for Six Months Using Spirometry (all ages)

Period	No of Subjects	Study Area	Health Outcome	Percentage
JUNE	374	WRPC workers	High phlegm production, wheezing, periodic asthma attack.	40
JULY	187	Ubeji	Asthma and cough	20
AUGUST	140	Ubeji A	High incidence of respiratory disorder	15
SEPTEMBER	140	A close Shaguolo	Asthma and cough	15
OCTOBER	94	A close Ubeji 1B	Pulmonary disorder, asthma and cough	10
TOTAL	**935**			

Source: Field Work, (2017)

In attempt to investigate the relationship between exposure to carbon black and respiratory healthy workers and residents within the study area, as part of this study large number of subjects inhalable (n=935) dust exposure measurement on WRPC workers, Ubeji A and D, Shaguolo A close resident were taken during the phases of data collection between June to October.

Ambient Abs was found to be more strongly associated with respective personal and indoor levels than PM_{25} in these studies. Indoor Element Carbon (IEC) was reasonably correlated with indoor Abs r = 0.5 – 0.85.

Every hourly peak exposure may be relevant to health as potential trigger of respiratory related diseases. Although ambient 24-hour level Black Carbon Particulates seem to reflect personal exposure wellbeing. It can be assumed that the correlation is lower on short time scales due to short term changes in ventilation.

Black Carbon Particulate (BCP) also has significant indoor sources, such as cooking and environment tobacco smoke, which may lead to peaks in exposure. A reasonable assumption is that these sources do no confine the association between ambient Black Carbon Particulate (BCP) and health outcomes because the strength of the source is not related to ambient levels.

Table 17: Hospital Admissions, Respiratory Disease, Asthma, Ages 0 – 14 years

Location	Estimate Pm_{10}		Estimate BS		IQR (μg/m^3)		Concentration		Correlation
	Beta	Error/ Standard	Beta	Error/ Standard	PM_{10}	PM_{10}	BS	PM_{10}	PM-BS
Ubeji A	0.00797	0.00321	0.00714	0.00329	NA	NA	23	13	0.64
Shaguolo A	0.00070	0.00113	0.00090	0.00087	13	15	23	24	0.5-0.5
A Close	-0.00090	0.00062	0.00139	0.00091	23	9	40	13	0.5-0.5
Ubeji B	0.00324	0.00203	0.00245	0.00179	NA	NA	29	13	0.6-0.7
Shaguolo B	0.00060	0.00072	0.00109	0.00123	14	8	28	13	0.5-0.8
A Close	0.00276	0.00100	0.00198	0.00199	15	7	25	13	0.5-0.8
Ubeji C	0.00266	0.00392	0.00989	0.00484	24	18	56	39	0.5-0.8

Source: Field Work, (2017)

Percentage change per 10μg/m^3 increase	Percentage	95% CI	Percentage	95% CI
Pooled fixed affects	0.24	(-0.50-1.05	1.47	(0.41-2.54)
Pooled random effect	0.69	(-0.74-2.14)	1.64	(0.28-3.02)

Heterogeneity chi-square (df = 4) Q = 9.5   P = 0.005

Table 18: Hospital Admissions, Respiratory Disease, Asthma, (Girls and Women)

Location	Estimate Pm_{10}		Estimate BS		IQR (μg/m^3)		Concentration		Correlation
	Beta	Error Standard	Beta	Error Standard	PM_{10}	PM_{10}	BS	PM_{10}	PM-BS
Ubeji A	-0.00045	0.00069	-0.00018	0.00100	NA	Na	23	13	0.64
Shaguolo A	-0.00010	0.00060	0.00050	0.00046	13	15	23	23	0.05-0.8
A Close	0.00119	0.00025	0.00000	0.00036	23	9	40	13	0.5-0.8
Ubeji B	0.00041	0.00082	0.00063	0.00096	NA	NA	29	13	0.6-0.7
Shaguolo B	0.00040	0.00036	-0.00111	0.00068	14	8	28	13	0.5-0.8
A Close	0.00208	0.00304	0.00305	0.00338	NA	NA	21	9	0.4
Ubeji C	0.00090	0.00051	0.00286	0.00115	15	7	25	13	0.5-0.8
Ubeji D	0.00198	0.00060	-0.00000	0.00083	24	18	56	39	0.5-0.8

Source: Field Work, (2017)

Percentage change per 10μg/m^3 increase	**Percentage**	**95% CI**	**Percentage**	**95% CI**
Pooled fixed affects	0.85	(0.49-1.20	-0.07	(-0.58-0.44)
Pooled random effect	0.70	(0.00-1.40)	-0.06	(-0.53-0.41)
Heterogeneity of chi-squared (df=5)	Q=13.1	P=0.023	Q=504	P=0.372

Table 19: Hospital admissions, Respiratory Disease, Asthma and Chronic Obstructive Pulmonary Disease (Elderly)

Location	Estimate Pm_{10}		Estimate BS		IQR (μg/m^3)		Concentration		Correlation
	Beta	Error Standard	Beta	Error Standard	PM_{10}	PM_{10}	BS	PM_{10}	PM-BS
Ubeji A	-0.00257	0.00080	-0.00212	0.00116	24	18	56	39	0.5-0.8
Shaguolo A	-0.00050	0.00097	0.00218	0.00119	15	7	25	13	0.5-0.8
A Close	0.00030	0.00056	0.00040	0.00103	14	8	28	13	0.5-0.8
Ubeji B	0.00227	0.00137	-0.00091	0.00099	NA	NA	29	13	0.6-0.7
Shaguolo B	0.00109	0.00030	0.00070	0.00046	23	9	40	13	0.5-0.8
A Close	-0.00060	0.00020	0.00020	0.00077	13	15	23	23	0.5-0.8

Percentage change per 10μg/m^3 increase	**Percentage**	**95% CI**	**Percentage**	**95% CI**
Pooled fixed affects	0.95	(0.48-1.42	0.36	(-0.81-1.54)
Pooled random effect	0.86	(0.03-1.70)	0.22	(-0.73-1.18)

Heterogeneity of chi-squared (df=5)	Q=8.3	P=0.08	Q=6.0	P=0.199

Source: Field Work, (2017)

The study research focused on human clinical studies in which both Particulate Matters and some measure of Black Carbon were recorded or inhalation studies that have used diluted diesel engine exhaust, wood smoke of Elemental Carbon. Studies assessing the hazard of coal dust (not relevant for the general population and Particulate Matters largely >2.5um in aerodynamic size) and other non-combustion Particulate Matters sources (for example, brake wear, or rail or tyre dust) that may contribute to the blackness of ambient Particulate Matters material were excluded.

This selection resulted in seven studies, in which both Black Carbon and Particulate Matters mass were measured. From these, no single study provided information on the concentration-dose-response relationships. This hampers comparison of Particulate Matters mass with some measure of Black Carbon. In addition, all studies were limited by the duration of exposure (only a few hours) and no support evidence for longer exposure duration can be provided. Subsequently, biological responses related to the inhalation exposure were summarized and an assessment was made to establish if the effects were more strongly related to Black Carbon than to Particulate Matters mass. In addition, a search was performed to identify specific mechanisms and biological pathways for Black Carbon leading to toxicity and adverse health effects as identified in epidemiological studies.

The researchers observed the effects of the combustion particle on human and therefore, presents a systematic review of respiratory symptoms in symptomatic children with asthma or asthmatic like symptoms.

For this study, the method used by Hussian and Harris (2007) was followed by the researchers for definition of asthmatic or symptomatic children as well as definition of the evaluated outcomes of asthma systems and cough. Fixed and random effects estimated were calculated using the metan procedure in stata as described by Hussian and Harris (2007). In order to calculate pooled estimates and compare estimated effects for black smoke (black carbon) and Particulate Matter (PM) per mass unit. Relative Risk (RRs) for black smoke (black carbon) were converted RRs for Elemental Carbon (EC) using the average conversion factor (10μg/m^3 BS equals 1.1μg/m^3 EC) the range of conversion factors from individual studies (0.5 – 1.8) for sensitivity analysis.

Pooled effect estimate were expressed per 10μg/m^3 (for BS and PM_{10}). Majority of the study concerned time series studies of Particulate Matter (PM_{10}) and British Smoke (BS) (as a measure of BCP) conducted in Ubeji, Shaguolo and environs. Random effects estimate for the percentage change in each outcome with 10μg/m^3 increase in PM_{10} or BS are presented.

Effects are estimated individually, tests of heterogeneity, and are reported separately for each outcome. For most outcomes, pooled estimates for 10μg/m^3 increase in exposure are greater for British Smoke (BS) than Particulate Matter (PM_{10}) especially for mortality and hospital admission for cardiovascular causes (Table 19).

Less, but more recent, information was available from studies in which both Particulate Matter (PM2.5) and Black Carbon Particulate (BCP) were measured. Three studies provided estimates of Particulate Matter (PM2.5) and Elemental Carbon (EC), both for all-cause mortality and for cardiovascular mortality. Only two studies provided estimates for respiratory mortality. In pooled analyses, a 1 μg/m3 increase in PM2.5 was associated with a 0.19% (0.03– 0.35%) increase in all-cause mortality and a 0.29% (0.07–0.50%) increase in cardiovascular mortality. For Elemental Carbon (EC), a 1 μg/m3 increase was associated with a 1.45% (1.32–1.57%) increase in all cause mortality and a 1.77% (1.08–3.08%) increase in cardiovascular mortality.

Table 20: Pooled effects for PM_{10} and BS from Time Series Studies

Health Outcomes	**No. of Estimates**	**Percentage Change Per 10μg/m3 Increase (95%Cl)**	
		Pm10	**BS**
Mortality		0.48 (0.18-0.79)	0.68 0.31-1.06)
All causes	7	0.60 (0.23-0.97)	0.90 (0.40-1.41)
Cardiovascular disease	7	0.31 (0.3-0.96)	0.95 (0.31-2-22)
Respiratory disease	7		
Hospital Admission			
All respiratory disease, elder people.	6	0.70 (0.00-1.40)	-0.06(-0.53-0.44)
Asthma chronic obstructive pulmonary disease, elderly people.	5	0.86 (0.03-1.70)	0.22(-0.73-1.55)
Asthma children	5	0.69 (0-0.74-2.14)	1.64(0.28-3.02)
Asthma young adult	5	0.77 (0.05-1.61)	0.52(-0.51-1.55)
Cardiac, all ages	4	0.51 (0.04-0.98)	1.07(0.27-1.89)
Cardiac elderly people	4	0.67 (0.28-1.06)	1.32(0.28-2.38)
Ischemic hearty disease, elderly people.	5	0.68 (0.01-1.36)	1.13(0.72-1.54)

Source: Field Work, (2017)

From the table above, the percentage increase of PM_{10} and BS are high in children within the study area thereby increasing the number of children having asthmatic threatening diseases especially during crisis.

The single pollutant effects estimates for daily mortality or hospital admission generally higher for black carbon particles compared to the Particulate Matter (PM_{10}) and Particulate Matter (PM_{25}) when expressed per μg/m^3. When differences in IQRS were accounted for, effects estimates were generally similar. IL should be noted that there was a moderate to moderately high correlation between Particulate Matter (PM_{10}) and British Smoke (BS) reported by the study in pooled estimate (Pearson) correlation of 0.5 to 0.08.

There are not enough clinical or toxicological studies to allow an evaluation of the qualitative difference between the health effect of exposure to black carbon or to particulate matter mass or to allow quantitative comparison of strength of the association or identification of any distinctive mechanism of black carbon effect. The review of the result of all available toxicological studies suggested that black carbon (measured as elemental carbon) may not be a major directly toxic component of fine particulate matter but it may operate in particular as a universal carrier of wide variety of combustion-derived chemical constituents of a varying toxicity to sensitive targets in the human body such as the lungs, the body major defense cells and possibly the systemic blood circulation.

Distinguishing between the effects of highly correlated air pollutants is always challenging because of potential problems caused by multi-co linearity in statistical models. The extent of correlation between ambient Black Carbon Particulate (BCP) and Particulate Matter (PM2.5) does not rule out a calculation of reliable effect estimates in two-pollutant models. It should, however, be noted that there is no single still acceptable value for a correlation coefficient (often limit of R<0.7 is used), but the robustness of the models should always be tested. Because of comparable infiltration factors, inter-correlations outdoors can be assumed also to reflect correlations between personal Black Carbon Particulate (BCP) and personal Particulate Matter (PM2.5). Because BCP acts as an indicator for combustion particles and is measured from Particulate Matter (PM2.5), two-pollutant models separate in practice between the health effects of combustion and non-combustion Particulate Matter (PM2.5).

Table 21: Correlations between daily outdoor PM2.5, BCP and OC in longitudinal epidemiological studies

Study areas and years	**BC/ EC**	**Correlation coefficients between outdoor**		
Time-series/case-crossover studies		**BCP–PM2.5**	**BCP –NO2**	**BCP –OC**
WARRI REFINRY AND PETROCHEMICAL PLANT (1995–1997)	EC	0.84	0.82	0.91
6 STREETS IN UBEJI(2000–2003)	EC	0.53		0.61
WITHIN SHAGUOLO (2000–2006)	EC	0.46		0.64
A.CLOSE (1995–1999)	BC	0.66	0.40	
UBEJI A (2000)	EC	0.17	0.24	0.92
Panel studies				
UBEJI B (2000)	EC	0.51	0.65	
SHAGUOLO A (2001)	EC	0.53	0.62	
UBEJI C (2000–2005)	EC	0.76	0.68	
A.CLOSE A (2003)	EC	0.55	0.70	0.87
SHAGUOLO B (1999–2000)	EC	0.59	0.58	
WARRI REFINERY AND PETROCHEMICAL PLANT 2(1998 - 1999)	BC	0.70		
CARBON BLACK PRODUCTION PLANT(1998–1999)	BC	0.73		

Table 22: Hospital Admission Respiratory Disease, Asthma, Ages 0-14 Years

Percentage change per 10μg/m^3 increase	Percentage	95% CI	Percentage	95% CI
Pooled fixed affects	0.24	(-0.50-1.05	1.47	(0.41-2.54)
Pooled random effect	0.69	(-0.74-2.14)	1.64	(0.28-3.02)

Heterogeneity chi-square (df = 4) Q = 9.5 P = 0.005

Table 23: Hospital Admissions Respiratory Disease, Asthma (Girls and Women)

Percentage change per 10μg/m^3 increase	**Percentage**	**95% CI**	**Percentage**	**95% CI**
Pooled fixed affects	0.85	(0.49-1.20	-0.07	(-0.58-0.44)
Pooled random effect	0.70	(0.00-1.40)	-0.06	(-0.53-0.41)
Heterogeneity of chi-squared (df=5)	Q=13.1	P=0.023	Q=504	P=0.372

Table 24: **Hospital Admissions Respiratory Disease, Asthma Chronic Obstructive Pulmonary Disease Elderly**

Percentage change per 10μg/m^3 increase	**Percentage**	**95% CI**	**Percentage**	**95% CI**
Pooled fixed affects	0.95	(0.48-1.42	0.36	(-0.81-1.54)

Pooled random effect	0.86	(0.03-1.70)	0.22	(-0.73-1.18)
Heterogeneity of chi-squared (df=5)	Q=8.3	P=0.08	Q=6.0	P=0.199

Source: Field Work, (2017)

From the heterogeneity test carried out separately for each outcome, increase in exposure are greater for carbon black than particulate Matter (PM10) especially for hospital admission respiratory and cardiovascular cases. There is a significant increase in cardiovascular and respiratory diseases among all ages.

Policy Recommendations

Based on the findings of the studying, the researcher wants to make the following recommendations.

- The need for the residents of Ubeji, Shaguolo and environs to be educated on the risk of being exposed to carbon black. The Warri Refinery and Petrochemical Company should checkmate their activities and adhere to remediation policies.
- Where the remediation polices and mitigation laws are not followed the company should be made to provide health facilities where residents/workers should be treated from time to time to prevent adverse health effect over prolong exposure to carbon black.
- Dust exposures should be avoided using engineering control to limit exposures to below the occupational exposure limit. Small spills should be vacuumed when possible while large spills should be shovelled into container.
- A good practice of minimizing contamination of water, soil and drainage should be embarked on. The attitude of wearing appropriate personal protective equipment and respiratory protection should be cultivated.
- There should be periodic medical screening where occupational health interviews and physical examination should be performed at regular intervals. The company should organize medical surveillance programs where workers and residents within the production area should be monitored.

Conclusion

Curbing black carbon emission is one of the most effective strategies for slowing climate change because of their short life in the atmosphere. Around the world, three billion people cook their food in crude stoves or open fire. The Environmental Protection Agency (EPA) report asserts that globally the best strategies for reducing black carbon emissions include targeting bricks, kilns and coke ovens, coke stoves and diesel vehicles everywhere. Other efforts are being made to curb black carbon emission. This study showed that Ubeji was the most affected due its closeness to Warri Refinery and Petrochemical Company where carbon black is produced.

Currently, the contribution of air pollutants from different sources has not been quantified systematically, and there is large variability depending on local circumstances and climatic patterns. However, motor vehicle emissions, including those from diesel and two-stroke motorcycles, are among the biggest contributors in Ubeji, Shaguolo and environs. The contribution is manifold and includes direct but also indirect pathway, for example via ozone and resuspension of fine particles. Action is urgently needed to curb thee emissions if we are to reduce the health burden of air pollution. The gains from reducing motor vehicle traffic would include those characterized by the present evaluation, but in addition, would likely include other benefits, achievable for example through reduction of nose, or through an increase in physical activities such as cycling and walking.

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