



AGE GROUP AND GENDER DISTRIBUTION OF NIGER DELTA RESIDENTS, WITH BLACK SOOT-INDUCED EYE DISEASES, IN SOME EYE CLINICS IN THE NIGER DELTA, BETWEEN 2017 AND 2021.

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ABSTRACT

This retrospective study compared the relationship between black soot and the prevalence of oculo-visual diseases among the residents of the Niger Delta Region, Nigeria, between 2017 and 2021. The study involved 4500 subjects (residents), 100 from each of the nine states of the Niger Delta, spanning the five year (2017 – 2021) period under study. The study population comprised males and females, between the ages of 11 and 60. The research design was anchored on document analysis, which was based on the clinical records of residents (patients) who visited the selected eye clinics in the capital cities of the Nine States of the Niger Delta region, with little or no history of such diseases prior to the period under study. The study identified some soot-induced eye diseases, like allergic conjunctivitis, corneal foreign body, dry eye/irritation, cataract, Pterygium and glaucoma, and determined their prevalence across the Nine States of the Niger Delta Region. It also determined the influence of age, gender and occupation on the oculo-visual impact of black soot on the Niger Delta residents. Occupation was categorized into indoor and outdoor workers for better organization and presentation. The data for this study were based on the clinical records of the residents (patients) who visited the selected eye clinics during the period under study. Percentages, arithmetic mean and standard deviation were used to determine the levels of the black soot-induced eye diseases. The sample *t*-test and analysis of variance (ANOVA) were used to determine the significance of average incidence of black soot-induced oculo-visual diseases, while the Fisher's least significant difference (LSD) method was used to determine the most prevalent black soot-induced eye disease(s) and the age group that was most affected. The findings showed a significant prevalence of black soot-induced eye diseases for all age groups, gender and occupation ($p \leq 0.05$). In all, Allergic Conjunctivitis (44.39%) has the highest prevalence of all black soot-induced eye diseases. Age group 21 – 30 was the highest affected by black soot-induced eye diseases with a percentage of 25.02, followed by age groups 11 – 20 (23.84%) and 31 – 40 (21.21%), respectively. Males were the highest affected by black soot-induced eye diseases with a percentage of 52.97. On the contrary, there is no significant difference in the effect of black soot induced eye diseases between male and female, across the Niger Delta States ($p = 0.104 < 0.05$). Generally, the findings show that there is no significant difference in the incidence of black soot induced eye diseases across the nine Niger Delta. In other words, the incidence of black soot-induced eye diseases across the nine Niger Delta states is virtually the same for all independent variables. Government failure to meet public demand for petroleum product, poverty and unemployment facilitate youth involvement in artisanal refinery activities, which caused the black soot pollution. It is important that government takes decisive actions to stop illegal oil business to prevent further pollution of Niger Delta environment, besides encouraging citizens to embrace healthy habits of personal hygiene and consumption of antioxidant rich fruits to neutralize the harmful effects of the soot.

KEYWORDS: age, gender, air pollution; black soot; eye diseases Niger Delta.

INTRODUCTION

Air is essential for the survival and development of all lives on Earth. Its quality directly affects human health, and it is strongly influenced by the level of civilization. Air pollution is a major factor to the global burden of diseases. There was increased mortality related to air pollution in both developing countries and developed countries such as the United States, despite more rigorous air quality standards.^[1] Although there are many natural sources of air pollution, for example, wildfires and volcanoes, since the Industrial Revolution, human technology has distributed the majority of substantial air pollution. The evolution of human civilization has been accompanied by industrialization and global transportation. Due to the development of industrialization, increasing numbers of fuel-burning motorized vehicles and factories have resulted in high levels of air pollution and poor air quality. For example, according to the Central Weather Bureau of Taiwan, the air quality index (AQI) in South Taiwan, where the main power plants of this island were located, was between 130~160 in January 2021, which is considered harmful to the normal population, necessitating restriction of outdoor activities.

There was growing outcry and understandable anxiety in some states of the Niger Delta region, over increasing presence of black soot, resulting in poor air quality. This problem was first observed in November 2016. Black soot is a black particulate matter made up of carbon, and results from the incomplete combustion of fossil fuels. Residents of the Niger Delta especially, in Rivers and Bayelsa States, and experts across Nigeria believe that illegal crude oil operations and the destruction of products from illegal oil refineries are responsible for the black soot. One of the causes (of the black soot) is the destruction of products that are gotten from illegal crude refineries; when such products are burnt, the smoke goes up into the atmosphere, both ambient and indoor environments, causing and/or aggravating cardiovascular diseases, respiratory conditions, skin and eye diseases, etc., with attendant irritation and discomfort.

In its concern about the black soot phenomenon in Rivers State, the Rivers State government linked the soot pollution to the activities of illegal oil refineries, bunkers and burning of tyres. Critical stakeholders are also concerned about this lingering problem that has become a serious public health issue. Hospitals and health centers in Port Harcourt have already confirmed an increase in the number of people with breathing difficulty.^[2]

The eye is the most important organ for human endeavor. The level of its functionality determines the rate and extent of human development and advancement, and by extension, the rate and extent of human capital development of a nation. From birth through childhood, adolescent to adulthood, any incapacitating oculo-visual health deficit will always impact negatively on the life and livelihood of the victims. Visually impaired persons do not

only lack appreciable capacity for productivity, in most cases, they are economic and social burden to the world around them. The policies and programs of best economies in the world are driven by visually healthy citizens. As our personal ambitions are anchored, mainly, on our ability to read, write, and understand, to see, appreciate and act, so the projection of human capital development of a nation is anchored on the oculo-visual capabilities of its workforce. Therefore, optimal oculo-visual health is sine qua non to human and national development. It is on this premise that the oculo-visual health of Niger Delta residents is now a concern, with respect to the black soot pollution in the area.

Good health plays a central role in nations economic development, and it is also a fundamental human right. For health to achieve this in any economy, the environment must play a significant role as the relationship between both cannot be denied. The environment is home to a wide range of resources that man uses to sustain his existence. In this sense, clean air, potable water, and nutritious food, etc. are environmental products that can help people live healthier and longer lives. Similarly, advances in agriculture, sanitation, and mineral exploitation for human sustenance have devalued the environment over time. Such devaluation has resulted in health issues. In this case, unsafe drinking water can cause a variety of infectious diseases like cholera, gastritis, diarrhea, meningitis, and schistosomiasis.^[3]

Analysis of Rivers State hospitals from 2014-2018 showed that in over 20,000 people who received care for soot-related conditions, black soot had caused adverse respiratory, skin and reproductive disorders. Eugene Abels, the initiator of the 'Stop-The-Soot' campaign, confirmed the report that, as of 2019, the death rate from black soot-related health issues in Rivers State had risen to 25,000, including babies.^[4]

Niger Delta Vigilante recalled that some residents of the university town of Otuoke in Ogbia Local Government Area of Bayelsa State and other parts of the state had earlier raised the alarm towards the twilight of the rainy season over what they described as black rain whenever there was downpour, but they did not take their worry serious until the soot appeared late November, 2013 as the clouds became a hazy grey. The problem is more pronounced in the morning hours when the thick blanket of black soot covers the landscape.^[5]

Disturbed residents are often seen pleading with the security agencies and, oil and gas surveillance contractors not to set boats laden with illegally refined petroleum products on fire again. This practice of burning confiscated petroleum products is adversely felt by residents in some parts of Niger Delta. Some of the adverse health impacts of this practice are respiratory tract irritation, (cough, catarrh), allergies, irritation of the eyes (itching, redness, tearing), irritation of the skin, exacerbation of asthma, lung

cancer, chronic bronchitis, chronic obstructive pulmonary disease, (COPD) and several other chronic lung diseases. It is worrisome that these hydrocarbon and black soot air pollution-related illnesses could assume an epidemic proportion, which may overwhelm the health facilities and health worker's capacity in affected states of the Niger Delta, leading to a sudden collapse of the health system. This black soot event has also polluted water, soil, contaminated plants, aquatic life and animals with associated health consequences after consumption.^[6]

Outdoor air pollution is a major environmental health problem that affects everyone, in low-, middle-, and high-income nations across the world. In the same way, black soot has become a major environmental health problem in the Niger Delta region of Nigeria. Ambient (outdoor) air pollution in cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2016. This mortality is due to exposure to fine particulate matter of 2.5 microns or less in diameter (PM_{2.5}), which cause cardiovascular and respiratory disease, and cancers.^[7]

People living in low- and middle-income countries unduly experience the problem of outdoor air pollution with 91% (of the 4.2 million premature deaths) occurring in low- and middle-income countries, with the greatest burden in the WHO South-East Asia and Western Pacific regions. The latest burden estimates reflect the very significant role air pollution plays in cardiovascular illness and death. More and more indicators of a link between ambient air pollution and cardiovascular disease risk is becoming available, including studies from highly polluted areas.^[8]

Some deaths could be attributed to more than one risk factor at the same time. For example, both smoking and ambient air pollution are factors in lung cancer. In this case, improving ambient air quality, or by reducing tobacco smoking could have prevented some lung cancer.

Additionally, 99 per cent of the global population is exposed to a high level of air pollution, which puts them at risk for heart disease, stroke, cancer, eye diseases, and other life-threatening medical conditions. Black soot, in particular, can be linked to a wide range of severe health effects, including acute bronchitis (an inflammation of trachea and bronchi that causes coughing) and an aggravated breathing situation for asthma patients.^[9] It is also a factor in allergic conjunctivitis, dry eye, pterygium/pinguecula, etc., and in aggravating pre-existing eye diseases, leading to visual impairment and blindness.

As the world continues to grapple with COVID-19, studies have indicated that air pollution could worsen the pandemic's impacts on people. With Omicron variant of the virus already detected in Nigeria, a major outbreak is expected in Port Harcourt (Rivers State) and Yanegoa (Bayelsa State) because the immune systems of many residents are highly reduced by the black soot incidence.

Presently, Nigeria has recorded over 200,000 COVID-19 cases, with over 13,000 cases (the third largest after Lagos and Abuja) found in Rivers State alone. Incidentally, nobody knows the forms and degree of oculo-visual discomfort suffered by this population.

In Rumuolumeni, Port Harcourt in the Niger Delta, environmental degradation is evident as the city and the region host all the oil activities, which, often times, degrade the environment. Such degradation takes place in form of oil spill and gas flaring. Over the years, a new dimension to this emerged due to air pollution, which is a product of rising cases of artisanal refineries, which, over time, produced black soot. The operators of these artisanal refineries rely on oil theft (Goodnews and Wordu, 2019). To curb this, the government set up Joint Military Taskforce (JTF) to monitor the activities of these operators. As it stands, illegal refineries are virtually in all coastal communities of the Niger Delta. The taskforce operation technique is to set these refineries on fire. Because the business is scattered everywhere, everyday artisanal refineries are set on fire, there is emission of an uncontrolled and uncontrollable thick black smoke (soot) pervading the sky, and clouding the cities. According to the Vanguard Newspaper of July 11, 2014, there were claims that JTF destroyed 110 illegal refineries. This, according to JTF, excludes 3,872 surface tanks used by operators of artisanal refineries, 191 barges, 13,129 drums, 785 wooden Cargo boats, 13,343 Jerry cans belonging to illegal oil business operators. Of great interest here is that as soon as the disruptions are made, the operators re-erect new ones. So the scenario is that of erect, destroy and re-erect. As this circle is maintained, so black smoke is emitted.^[10]

Over the years, soot has been classified as a threat to public health. Public health, generally, is concerned with promoting and protecting the health of people and the community where they live, learn, work and play. By this, an incidence that is capable of affecting negatively the safety and well-being or improvement in the health of the people is considered a public health problem. This theory specifically claims that man and nature are in an interdependent relationship. This sentiment of the close affinity between nature and man is further emphasized by Rift theory which sees the relationship as dynamic, and that the dynamics are between humans and non-humans in the natural world, which for them are distinct entities, but are united within one metabolic system.^[11]

Theoretically, several theories exist in this regard. Gibson's ecological psychology theory, a derivation of general ecological theory views organism and environment as inseparable pair. The critical feature of Gibson's conception of the pair between organism and environment is that the environment and the individual interact, and influence each other. That is, the action of an individual influences the environment, and is influenced in return by the other. So, both are in an inseparable relationship, and a

part of a greater whole. Arising from this, an applied ecological theory strengthened the affinity between organisms and the environment further. Among its core assumptions is that human beings like other organisms are parts of the web of life which induce both interrelated and interdependent contacts. Human being depends on the environment and its resources. That is, both enjoy mutual influences. The striking thing in this ecological theory is that one thing (whether negative or positive), which occurs in this mutual influence between organism and the environment, produces an equivalent event on the other. When the individual in the environment, for example, abuses the environment when he exploits the resources endowed in the environment, such abuse produces negative consequences on man. Similarly, Marxian ecological theorist like O'Connor provides an understanding of this relationship but anchors more on the capitalist quest for materialism, which has resulted in providing adverse ecological consequences that threaten the stability of nature. Meaning that capitalism curious desire to provide and gain private materials did not only create ecological in-balance, but that this in-balance can cause several problems, including health problems for man. Eco-socialists like Kovel and Lowy on their part believe that capitalist expansion has resulted in an environmental crisis in its quest or drive to industrialize. Through this, capitalism created ecological in-balance which, on its own, is causing several problems, health problem inclusive.^[12]

Various studies have investigated the health impact of black soot on the residents of the Niger Delta region, especially with respect to the respiratory and cardiovascular systems. Unfortunately, there is no appreciable effort at examining the relationship between black soot and oculo-visual health of the residents of the region. In recent times, black soot pollution has become a factor in the increased cases of eye diseases and deterioration of existing eye defects as responses to changes in the environment occasioned by black soot

pollution. Surprisingly, there is no report of scientific investigation into the nature and degree of adverse effects of black soot pollution on oculo-visual health of the residents of the Niger Delta region. Furthermore, it is also important to understand the levels of this relationship in each of the nine states of the Niger Delta, with main focus on their capital cities.^[13] In other words, this work is the first large-scale study on the impact of black soot on the oculo-visual health of the Niger Delta residents. Hence, the need to compare the relationship between black soot and the prevalence of oculo-visual diseases among the residents with Age group and gender distribution.

MATERIALS AND METHODS

Study Design

The study was a retrospective survey study to compare the relationship between black soot and the prevalence of oculo-visual problems among the residents of the Niger Delta Region of Nigeria, between 2017 and 2021, relying on the clinical (medical) records of the patients who visited selected eye clinics in a period of five years of the black soot incident, between 2017 and 2021. The research design of this study was anchored on document analysis, which was based on the clinical records of patients (residents) who visited the selected eye clinics in the capital cities of the nine states of the Niger Delta region of Nigeria during the period under study, with little or no history of such diseases prior to the period under study.

Area of the Study

This study was carried out across the capital cities of the Niger Delta region in Nigeria, involving some selected private and public facilities (eye clinics).

The Niger Delta is the oil-rich region of Nigeria, located in the south of the nation and on the delta of "River Niger". Nine oil-producing states make up the Niger Delta, namely, Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers.

GPS of Study Areas

Hospitals

Federal Medical Center Umuahia
University of Uyo Teaching Hospital
Federal Medical Center, Yenagoa
University of Calabar Teaching Hospital
Federal Medical Center, Asaba
University of Benin Teaching Hospital
Federal Medical Center, Owerri
Federal Medical Center, Owo-Akure
University of Port Harcourt Teaching Hospital

Latitude

5.5195° N
5.01156° N
4.9372° N
4.950° N
6.71236° N
6.3337° N
5.476310° N
7.217460° N
4.8998° N

Longitude

7.4966° E
7.861352° E
6.2667° E
8.3502° E
6.71236° E
5.6001° E
7.025853° E
5.597658° E
6.9289° E

Study Population

The population for this study comprised a total of 4500 male and female outpatients, 100 from each of the capital cities of the 9 states that make up the Niger Delta region, between the ages of 11 and 60 (organized into 5 age groups), covering the study period of five years (2017 –

2021). The age groups are: A (11 – 20 years), B (21 – 30 years), C (31 – 40 years), group D (41 – 50 years) and group E (51 – 60 years), as presented on the data (table 4.1). The study population included, only individuals, who visited the selected private and public health facilities (eye clinics) in the capital cities of the nine states of the Niger

Delta region, Nigeria during the period (2017 – 2021) under study, and by their clinical records, had little or no history of such diseases prior to the period under study. The choice of the use of the selected eye clinics was informed by the ease of accessing patients' records, with little or no administrative bottlenecks.

Sample and Sampling Technique

In this respect, the study population was first sampled according to the symptoms and nature of eye conditions observed in the capital cities of the Niger Delta region of Nigeria. It was further classified into five age groups, and by gender (male and female). The occupations of the population were also categorized into indoor and outdoor workers. Generally, and specifically, the data were arranged in line with what obtained in the nine states (represented in the capital cities) of the Niger Delta, within the period(s) under study. The data collected were presented, using frequency tables.

Instruments for Data Collection

Majorly, the data for this study were based on the clinical records of the regular patients who visited the selected eye clinics during the period under study. However, the following instruments were used for clinical examinations and diagnoses of the patients (subjects):

1. Snellen's visual acuity charts for far and near visual acuity measurements.
2. Pen torch for external eye examination
3. Ophthalmoscope for internal (fundal) eye examination.
4. Retinoscopy for objective evaluation of the subjects' refractive errors
5. Slit lamp biomicroscope for comprehensive examination of the external and internal structures of the eyes of the subjects (patients).
6. Perkins tonometer for standard measurement of the intraocular pressure of the subjects.

Statistical Analysis

Percentages, arithmetic mean and standard deviation were used as methods to describe the level of black soot-induced oculo-visual diseases in the Niger Delta region (2017 – 2021). The sample *t*-test and analysis of variance (ANOVA) were used to determine whether the average incidence of black soot induced oculo-visual diseases is significant in the Niger Delta States between 2017 and 2021, while the Fisher's least significant difference (LSD) method was used to determine the most prevalent black soot-induced oculo-visual disease(s) in the Niger Delta region between 2017 and 2021, and the age group that is most highly affected.

RESULTS

Table 1: Age group distribution of Niger Delta residents who visited selected eye clinics in the Niger Delta, between 2017 and 2021.

Age group											Total	
States	A(11 - 20)		B(21 - 30)		C(31 - 40)		D(41 - 50)		E(51 - 60)			
	Freq.	% freq.	Freq.	% freq	Freq.	% freq.	Freq.	% freq.	Freq.	% freq	Freq.	% freq
Abia	156	3.47	107	2.38	79	1.76	71	1.58	87	1.93	500	11.11
Akwa Ibom	146	3.24	109	2.42	88	1.96	76	1.69	81	1.8	500	11.11
Bayelsa	113	2.51	125	2.78	106	2.36	77	1.71	79	1.76	500	11.11
Cross River	102	2.67	134	2.98	117	2.6	79	1.76	68	1.51	500	11.11
Delta	144	3.2	134	2.98	88	1.96	61	1.36	73	1.62	500	11.11
Edo	122	2.71	141	3.13	123	2.73	67	1.49	47	1.04	500	11.11
Imo	99	2.2	119	2.64	132	3.93	80	1.78	70	1.56	500	11.11
Ondo	143	3.18	112	2.49	100	2.22	68	1.51	77	1.71	500	11.11
Rivers	116	2.57	116	2.58	107	2.38	83	1.84	78	1.73	500	11.11
Total	1141	25.75	1097	24.38	940	21.9	662	14.72	660	14.66	4500	100

Table 1 is the age group distribution of Niger Delta residents who visited selected eye clinics in the Niger Delta, between 2017 and 2021. It shows that out of the 4500 residents of the Niger Delta, who visited selected eye clinics in the Niger Delta, age group A had the highest

residents' turnout of 1141 (25.75%); followed by age group B, with 1097 (24.38%) residents; age group C had 940 (21.90%) residents; age group D had 662 (14.72%) residents, and age group E had 660 (14.66%) residents.

Table 2: Age group distribution of Niger Delta residents, across the Nine states of the Niger Delta, who presented with black soot-induced eye diseases, to the selected eye clinics in the Niger Delta, between 2017 and 2021.

S/N	Niger Delta States	A(11 -20)		B(21 - 30)		C(31 - 40)		D(41 - 50)		E(51 - 60)		Total	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
1	Abia	125	3.25	94	2.45	64	1.67	55	1.43	79	2.06	417	10.85
2	Akwa Ibom	143	3.72	104	2.71	81	2.11	65	1.59	64	1.67	457	11.89
3	Bayelsa	108	2.81	123	3.2	106	2.76	74	1.93	77	2	488	12.7
4	Cross River	80	2.08	123	3.2	105	2.73	71	1.85	62	1.61	441	11.48
5	Delta	104	2.71	109	2.84	76	1.98	53	1.38	67	1.74	409	10.64
6	Edo	66	1.72	104	2.71	94	2.45	45	1.17	34	0.88	343	8.93
7	Imo	89	2.32	111	2.89	127	3.3	76	1.98	63	1.64	466	12.13
8	Ondo	88	2.29	77	2	55	1.43	43	1.12	62	1.61	325	8.46
9	Rivers	113	2.94	116	3.02	107	2.78	83	2.16	78	2.03	497	12.93
	Total	916	23.84	961	25.02	815	21.21	565	14.61	586	15.24	3843	100

Table 2 is the age group distribution of Niger Delta residents, across the Nine states of the Niger Delta, who presented with black soot-induced eye diseases, to the selected eye clinics in the Niger Delta, between 2017 and 2021. It shows that out of the 3843 of residents who presented with black soot-induced eye diseases, the

highest residents' turnout of 961 (25.01%) was from age group B (21-30). This is followed by age group A (11-20); age group C (31-40) had 815 (21.21%) residents; age group E (51-60) had 586 (15.24%); and age group D (41-50) had the least residents' turnout, with 565 (14.61%) residents, in that order.

Table 3: Gender distribution of Niger Delta residents who visited selected eye clinics in the Niger Delta, between 2017 and 2021.

S/N	Niger Delta States	M		F		Total	
		Freq.	%	Freq.	%	Freq.	%
1	Abia	257	5.71	243	5.4	500	11.11
2	Akwa Ibom	272	5.73	228	5.06	500	11.11
3	Bayelsa	256	5.69	244	5.42	500	11.11
4	Cross River	247	5.49	253	5.62	500	11.11
5	Delta	257	5.71	243	5.4	500	11.11
6	Edo	246	5.47	254	5.64	500	11.11
7	Imo	256	5.69	244	5.42	500	11.11
8	Ondo	247	5.49	253	5.62	500	11.11
9	Rivers	271	6.02	229	5.09	500	11.11
	Total	2309	51.31	2191	48.69	4500	100

Table 3 is the gender distribution of Niger Delta residents who visited selected eye clinics in the Niger Delta, between 2017 and 2021. It shows that out of the 4500 residents,

2309 (51.31%) residents were males and 2191 (48.69%) residents were females.

Table 4: Gender distribution of Niger Delta residents who presented with black soot-induced eye diseases, across the Nine states of the Niger Delta, to selected eye clinics in the Niger Delta, between 2017 and 2021.

S/N	Niger Delta States	M		F		Total	
		Ferq.	%	Freq.	%	Freq.	%
1	Abia	214	5.57	203	5.28	417	10.85
2	Akwa Ibom	258	6.72	199	5.18	457	11.89
3	Bayelsa	252	6.56	236	6.14	488	12.7
4	Cross River	231	6.01	210	5.46	441	11.48
5	Delta	220	5.72	189	4.92	409	10.64
6	Edo	178	4.63	165	4.29	343	8.93
7	Imo	241	6.27	225	5.85	466	12.13
8	Ondo	172	4.48	153	3.98	325	8.45
9	Rivers	270	7.03	227	5.91	497	12.93
	Total	2036	52.99	1807	47.01	3843	100

Table 4. is the gender distribution of Niger Delta residents who presented with black soot-induced eye diseases, across the Nine states of the Niger Delta, to selected eye clinics in the Niger Delta, between 2017 and 2021. It shows that out of the 3843 residents of the Niger Delta, who presented with black soot-induced eye diseases, there were 2036 (45.24%) males with black soot-induced eye diseases and 273 (6.07%) males without black soot-induced eye diseases; 1807 (40.15%) females with black soot-induced eye diseases and 384 (8.53%) females without black soot-induced eye diseases.

DISCUSSION

There was an incidence of black soot in the Niger Delta, which became a complex environmental problem. The prime source of the black soot is the artisanal refineries (Kpo Fire) scattered all over the Niger Delta Region. This action is caused by the marine eco-system of the Niger Delta, which makes it possible for illegal oil business due to government failure to meet public demand for petroleum products; a situation that facilitates the relevance of artisanal refinery. Equally significant is the frequent continued burning down of artisanal refineries infrastructure by the government task force on illegal oil business. The occurrence of black soot, which started in 2016, and lasted till 2022, degenerated into a real and potential public health problem, impacting negatively on the oculo-visual health and the general health of the residents of the Niger Delta.^[14]

The purpose of this retrospective study was to compare the relationship between black soot and the prevalence of oculo-visual problems (eye diseases) among the residents of Niger Delta Region, Nigeria, between 2017 and 2021. This chapter comprises a discussion of major findings as connected with the literature on black soot pollution, observed black soot-induced eye diseases and their effect on the visual health of the Niger Delta residents, with respect to their age, gender and occupation. The study also compared black soot effect among the states of the Niger Delta. The study population was 4500 subjects, 100 from each state of the Niger Delta, spanning the period of 5 years (2017 – 2021) under study.^[15]

The study identified allergic conjunctivitis, cataract, corneal foreign body, dry eyes/irritation, glaucoma and pterygium as the major black soot-induced eye diseases suffered by Niger Delta residents, across Niger Delta States between 2017 and 2021.

The adverse effects of air pollutants such as CO, NO_x, PM, and O₃ on human eyes consist of mostly irritation and inflammation, with conjunctivitis being a frequent problem (Schwela *et al*, 2000). The study showed that allergic conjunctivitis (AC) had the highest level of incidence of 44.39%; this was followed by dry eye/irritation with 21.96% prevalence and pterygium with 17.10%, with mean values of 189.6, 93.78 and 73.00, respectively, across the nine States of the Niger Delta. This

highest prevalence of allergic conjunctivitis supports the finding by^[16] that showed conjunctivitis as the most common eye disease diagnosed in emergency departments, wherein it accounts for almost one third of all eye-related diseases, in the United States. It is also in line with a previous study that reported that conjunctivitis was aggravated by exposure to ambient air pollution.^[17] In this case, black soot pollution. This finding further supports the report that exposure to air pollution could significantly increase the risk of developing conjunctivitis particularly, allergic conjunctivitis.^[18] Conjunctivitis is one of the most commonly diagnosed conditions in optometric patients and emergency room visits.^[19] It is, therefore, not out of place that our findings also showed allergic conjunctivitis as the most prevalent eye disease during the period under study.

Allergic conjunctivitis is a common eye disease that affects all ages. This is in line with our findings that equally showed that allergic conjunctivitis had universal spread in terms of age group during the period under study. However, regardless of the widespread prevalence of allergic conjunctivitis in this study, we found that age group 21 – 30 was the highest affected by black soot-induced eye diseases with a percentage of 25.02, followed by age groups 11 – 20 (23.84%) and 31 – 40 (21.21%), with mean values of 106.78, 101.78 and 90.11, respectively. The highest prevalence recorded among these age groups may be due to the fact that these age groups were mostly involved in itinerant outdoor activities, which exposed them more to black soot pollutants. Our findings also showed that age group 41 – 50 had the least prevalence of allergic conjunctivitis, with 14.71%, followed by age group 51 – 60, with 15.22%, with mean values of 62.78 and 65.11, respectively. Conversely, the low prevalence of allergic conjunctivitis recorded among these age groups may be because these age groups were least involved in outdoor activities during the black soot incidence.^[20]

The result shows that the males were the highest affected by black soot-induced eye diseases with a percentage of 52.97, contrary to females, with 47.03%, with mean values of 226.2 and 200.76, correspondingly. Men are naturally more outgoing, and indulged in more outdoor activities than woman. Therefore, it may not be out of place that our study showed a similar pattern in the prevalence of allergic conjunctivitis.

Unfortunately, our finding on gender influence on the prevalence of allergic conjunctivitis during the period under study could not settle the controversy between the findings of ^[16], with their conflicting results as to which gender, with conjunctivitis, was more affected by O₃, one of the constituents of ambient air pollutants.

Traffic- and industry-related airborne byproducts account for most outdoor air pollution. For example, in New Delhi, India, the transportation component of air pollution was

72%, and the industry component was 20% in 2003.^[17] The level of suspended particulate matter (SPM) in New Delhi was five times higher than the annual average control limit of $60\mu\text{g}/\text{m}^3$ set by the . NO and NO₂, the primary products of diesel oil consumption by trucks and large vehicles, can travel long distances. Higher nitric oxide (NO) and NO₂ concentrations were related to more severe conjunctivitis in people in Paris.^[18] Another study from Taiwan reported that visiting an outpatient eye clinic was associated with an increased chance of visiting an eye clinic for nonspecific conjunctivitis due to increased exposure to PM₁₀ and PM_{2.5}, NO₂, SO₂, and O₃.^[19] One study in New Delhi showed that people who commuted daily to the workplace using open vehicles (e.g., scooters, motorcycles, or bicycles) for more than 10 years had more ocular surface symptoms, such as redness, irritation, lacrimation, burning, and dryness, than people living near their workplace.^[20] Our findings showed a similar trend in the prevalence of black soot-induced eye diseases in which outdoor workers were more affected, with a percentage of 68.12 than indoor workers, 31.88%, with mean values of 290.1 and 136.11, respectively.

Air pollution jeopardizes the survival of humans, and also impacts everyday living in societies. It is a common knowledge that outdoor air pollution influences health. Air pollution causes many health problems and diseases, such as cardiovascular disorders, respiratory tract problems, ocular disease, neurologic disease, cancer, and death.^[21]

The cornea is the most sensitive structure in the human body due to numerous innervations in the ocular surface and, thus, is extremely sensitive to environmental agents. The eyes are protected against potentially harmful external materials with only a thin layer of precorneal tear film; consequently, human eyes are predisposed to the adverse effects of air pollution.^[22]

The adverse effects of air pollutants such as CO, NO_x, PM, and O₃ on human eyes consist of mostly irritation and inflammation, with conjunctivitis being a frequent problem. Numerous studies have tried to determine the impact of environmental toxins on the ocular surface.

Cataracts can also be caused by exposure to tobacco smoke. There is, also, a relationship between age-related macular degeneration (AMD) and exposure to traffic-related air pollutants. Our findings appear to incline to the above facts, showing that Niger Delta residents who suffered from black soot-induced eye diseases were more, with a percentage of 85.41 than residents without black soot-induced eye diseases (14.59%), having mean values of 20.1 and 20.1, respectively. Continuous exposure to air pollution can cause cellular transformation, including goblet-cell hyperplasia in the human conjunctival epithelium.^[23] Discomfort due to eye disorders can interfere with people's daily work efficiency and reduce road traffic safety. Furthermore, air pollution may aggravate dry eye disease.^[24]

Air pollution level in Rivers State is higher than the World Health Organization standard, and it was attributable to the high morbidities and mortalities in the State.^[25] This level of air pollution gave rise to cerebrospinal meningitis (CSM), chronic bronchitis, measles, pertussis, pulmonary tuberculosis, pneumonia, and hyper respiratory tract infection, with pneumonia accounting for the highest incidence of deaths in the state. A study of environmental risk factors and hospital-based cancers in two Nigerian cities reported a close relationship between air pollution, including soot, and diseases, such as respiratory diseases, traumatic skin outgrowth, respiratory health condition, child deformities, stillbirth and miscarriage. Different studies have related adverse health problems like eye and skin disorders with people who are frequently exposed to polluted air.^[26]

The cornea is the most sensitive structure in the human body due to numerous innervations in the ocular surface and, thus, is extremely sensitive to environmental agents. The eyes are protected against potentially harmful external materials with only a thin layer of precorneal tear film; consequently, human eyes are predisposed to the adverse effects of air pollution.

In this study, using Analysis of Variance, it was found that the incidence of black soot induced eye diseases was significant across the Niger Delta States between 2017 and 2021 ($p < 0.05$). Several studies have tried to determine the impact of environmental toxins (pollutants) on the ocular surface. In line with our findings, it was reported that persons who traveled to highly polluted areas where the PM level was five times higher than the WHO annual average limit of $60\mu\text{g}/\text{m}^3$ suffered from extensive subclinical ocular surface changes.^[27]

Human eyes are very vulnerable to the harmful effects of air pollution. The ill effects of air pollution on human eyes are mostly irritation and inflammation, with conjunctivitis being a significant problem. Numerous research studies have tried to determine the effects of environmental toxins on the ocular surface. One study showed that, among persons who travelled regularly through high-polluted areas, a considerable portion suffered from subclinical ocular surface changes. In another research investigation, it was observed that air pollution contributed to cell alterations and ocular surface inflammation, leading to ocular discomfort.^[28]

In this study, and using the Fisher's least significant difference (LSD) method, it was revealed that, among the black soot-induced eye diseases suffered by Niger Delta residents, across the States of the Niger Delta States, between 2017 and 2021, allergic conjunctivitis was the most significant, with a mean value of 189.6, followed by dry eye/irritation. Pterygium and cornea foreign body had the same effect on the residents of Niger Delta States, while cataract and glaucoma also had the same, but least significant effect across the nine States of the Niger Delta.

In line with our findings, conjunctivitis is one of the most commonly diagnosed conditions in optometric patients and emergency room visits. According to data from the Bureau of Taiwan National Health Insurance, more than 40% of patient visits are diagnosed with conjunctivitis annually. Conjunctival disorders induced by air pollution can cause subclinical ocular surface but on many occasions with serious discomforts, such as burning and irritation, which require clinical attention. Moreover, chronic exposure to air pollution can induce cellular changes, such as goblet-cell hyperplasia in the ocular surface.^[29] The discomforts of ocular diseases, such as burning, irritation, itching, and tearing interfere with people's daily activities including work efficiency and road safety. However, treating ocular diseases with steroid eye drops occasionally results in cataracts, glaucoma, and other severe adverse effects, which may lead to permanent loss of vision.^[30]

Low- and middle-income countries excessively experience the problem of outdoor air pollution with 91% (of the 4.2 million premature deaths) occurring in low- and middle-income countries, with the greatest burden in the WHO South-East Asia and Western Pacific regions. The latest air pollution disease burden estimates show the very important role air pollution plays in cardiovascular illness and death. More and more indicators of a link between ambient air pollution and cardiovascular disease risk is becoming available, including studies from highly polluted areas.^[31]

Some deaths could be attributed to more than one risk factor at the same time. For example, both smoking and ambient air pollution are factors in lung cancer. In this case, improving ambient air quality, or by reducing tobacco smoking could have prevented some lung cancer.

A 2013 assessment by WHO's International Agency for Research on Cancer (IARC) concluded that outdoor air pollution is carcinogenic to humans, with the particulate matter component of air pollution most closely associated with increased cancer incidence, especially lung cancer. It has also been observed that there is an association between outdoor air pollution and increase in cancer of the urinary tract/bladder.

About 99 per cent of the global population is exposed to a high level of air pollution, which puts them at risk for heart disease, stroke, cancer, eye diseases, and other life-threatening medical conditions. Black soot, in particular, can be linked to a wide range of severe health effects, including acute bronchitis (an inflammation of the airways in the lungs, the bronchi, that causes coughing) and an aggravated breathing situation for asthma patients.^[32] It is also a factor in allergic conjunctivitis, dry eye, Pterygium, pinguecula, etc., and in aggravating pre-existing eye diseases, leading to visual impairment and blindness.^[33]

Incidentally, none of the reports established that age is a factor in air pollution diseases. This is in line with our findings, which showed that the incidence of black soot-induced eye diseases among the age groups is significant ($p < 0.05$). In other words, black soot-induced eye diseases, within the period under study affected Niger Delta residents, irrespective of their age group.

However, using the Fisher LSD Method, it was found that the effect of black soot-induced Eye Diseases across Niger Delta States had more (and equal) significance on, age groups 11 - 20, 21 - 30 and 31 - 40 than on age groups 41 - 50 and 51 - 60. This difference in significant effect may be due to the fact that age groups 11 - 20, 21 - 30 and 31 - 40 were younger and more involved in outdoor activities during the period under study than age groups 41 - 50 and 51 - 60. Incidentally, our findings, with respect to age, do not support the study by^[34], which showed a positive relationship between dry eye syndrome and an imbalance of sex steroid hormone (SSHs) associated with advanced age especially, in menopause. Furthermore, dry eye affects twice as many women as men over 50 years of age.^[35]

Dry eye syndrome is most likely related to an imbalance of sex steroid hormone (SSHs) associated with advanced age mainly menopause ^[36] Many causes of dry eye disease are exclusive to women. On the average, women are diagnosed with dry eye 6 years earlier than men, resulting in serious incapacity as a chronic condition. Women also reported higher levels of dry eye symptoms, greater use of dry eye treatment and a greater adverse effect on quality of life.^[37]

Contrarily, our findings showed no significant difference between males and females in relation to black soot induced eye diseases across the Niger Delta States ($p = 0.104$).

Pregnancy can also trigger dry eyes. Environmental allergens, toxins, and other irritants, like exposure to air conditioning, wind, excessive sunlight, dust, contact lenses, smog and smoke, contribute as well. For example, in one study, 40% of dry eye patients were smokers. Also, second hand cigarette smoke reduces tear breakup time by 40%. Even a single cigarette can produce a level of carbon monoxide of 400 ppm (parts per million). In their study of 1356 women to determine if black smoke and Sulphur dioxide are risk factors for dry eye disease, It has been shown that there is association between long-term exposure to ambient air pollutant concentrations and dry eye disease (DED) in women of reproductive age.

There is evidence that sex is a factor in the development and progression of glaucoma. The Rotterdam Study demonstrated increased risk of primary open angle glaucoma (POAG) in women with early menopause.^[38] Second, women are at higher risk for primary angle closure glaucoma (PACG) likely due to anatomical predisposition.^[39] Third, female gender was found to be a risk factor in normal tension glaucoma. Lastly, the changes

in the level of female sex hormones may influence intraocular pressure (IOP) as well as vascular resistance that might affect the optic nerve head circulation. As women go through cycles of hormonal changes, this might potentially influence the onset and the course of the [40] Accordingly, gender and/or changes in sex hormone levels should be taken into consideration in the care of patients with glaucoma. These also contradict our findings on gender difference relative to the significance of black soot-induced eye diseases cross the Niger Delta States, during the period under study.

CONCLUSION

Black soot exists and it has become a complex environmental problem. The prime source is the artisanal refineries (Kpo Fire) scattered all over the Niger Delta Region. The study showed that there was a significant effect of back soot pollution on the visual health of the residents of the Nigerian Niger Delta during the peak period (2017 to 2021) of black soot incidence. This era of black soot pollution impacted negatively on the oculo-visual health of the residents of the Niger Delta Region, causing eye discomfort, including irritation, foreign body sensation, etc. the effect of these eye cuts across age group, gender and occupation, with greater effect on adolescents and young adults, males and outdoor workers. This event is occasioned by the marine eco-system of the Niger Delta, which makes it possible for illegal oil business due to government failure to meet public demand for petroleum product; a situation that facilitates the relevance of artisanal refinery. Equally significant is the frequent continued burning down of artisanal refineries infrastructure by the government task force on illegal oil business. Poverty and unemployment were also factors in youth involvement in this activity. Besides government action to stop this illegal business to prevent further pollution of Niger Delta environment, residents of the Niger Delta should be encouraged to embrace healthy habits of personal hygiene and consumption of antioxidant rich fruits to neutralize the harmful effects of the soot, among other recommendations.

This study has brought to the fore the adverse effects of air pollution (black soot) on eye health, especially among the Nigerian Niger Delta residents. It also offers an insight into measures that can be taken to prevent an incidence or completely stop the exhalation of air pollution, the black soot incidence. This can be done by conversion of these artesanal refineries to modular refineries, and creation of job opportunities for the ever increasing unemployed youths of the Niger Delta by the governments.

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