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Review

Air Pollution, Climate Change and Ecosystem Health in the Niger Delta

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Abstract: There are interactions and feedbacks between air pollution as a driver of environmental change, climate change, and overall ecosystem health. Air pollution is a major environmental problem, particularly in developing countries where regulations may be lax. This paper explores the nexus between air pollution, climate change and overall ecosystem health in the Niger Delta region of Nigeria. It brings novelty by exploring these issues with an environmental justice lens. This is particularly pertinent due to the ecological sensitiveness of the region and the high dependence of the indigenes on the land and water. The region's ecosystem is becoming more and more threatened as pollution increases and the climate changes further. Nigeria's position as the largest oil producer in Africa and the sixth largest in the world is due to the oil and gas reserves of its Niger Delta region. The irony becomes that while the region is the mainstay of the Nigerian economy or is a source of national 'good', they have received in return only environmental 'bads'. The many levels of deprivation experienced by the indigenes of the Niger Delta is a classic case of environmental injustice where the region disproportionately bears a much higher burden of air, land, and water pollution in comparison to other parts of the country. Gas flaring, fossil fuel burning, artisanal refining of crude, and transportation are found to be the main sources of air pollution in the locality. Mitigating air pollution and the attendant impacts requires urgent action and concerted effort at the individual, local and national levels. This paper provides recommendations in this regard.

Keywords: pollution; environmental degradation; environmental justice; air quality; environmental health; environmental problem

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1. Introduction

Air pollution is a major environmental problem, particularly in developing countries (Mannucci and Franchini 2017). The emission and transmission of air pollutants cause air pollution (Mayer 1999). Nigeria, Africa's most populous nation of over 200 million (Echendu 2020a), is plagued with numerous environmental problems one of which is air pollution. The air quality in its major cities ranks among the worst in the world (Okon 2019). In a World Health Organization (WHO) five-year period (2008–2013) assessment of levels of particle pollution in the air ($PM_{2.5}$ and PM_{10}), four major Nigerian cities ranked in the top 20 of the most polluted cities in the world, in terms of the annual mean concentration of PM_{10}. Onitsha was the worst polluted city with a record 30 times higher than the WHO's recommended 20 $\mu g/m^3$ annual mean (Yakubu 2018).

The Niger Delta area of Nigeria is one of the most underprivileged parts of the country despite being the mainstay of the country's economy (Adekola and Mitchell 2011; Babatunde 2020). Figure 1 is a map of the Niger Delta. This oil-rich region suffers serious air pollution for reasons that will be elaborated on in this paper. There has been significant albeit disparate interest in the prevalence of various forms of pollution, including air pollution in the region, but no study has explored the nexus between air pollution, climate

change, and overall ecosystem health—a gap this study fills. The failure to investigate their interconnections is a significant oversight because recognizing important problems in silos without understanding their interactions could lead to sub-optimization and failure to harness the co-benefits of addressing these problems. Some of these co-benefits can be seen when air pollution reduces and atmospheric warming slows down. This would improve the general climate conditions, which then improves the overall environmental, social, and economic well-being.

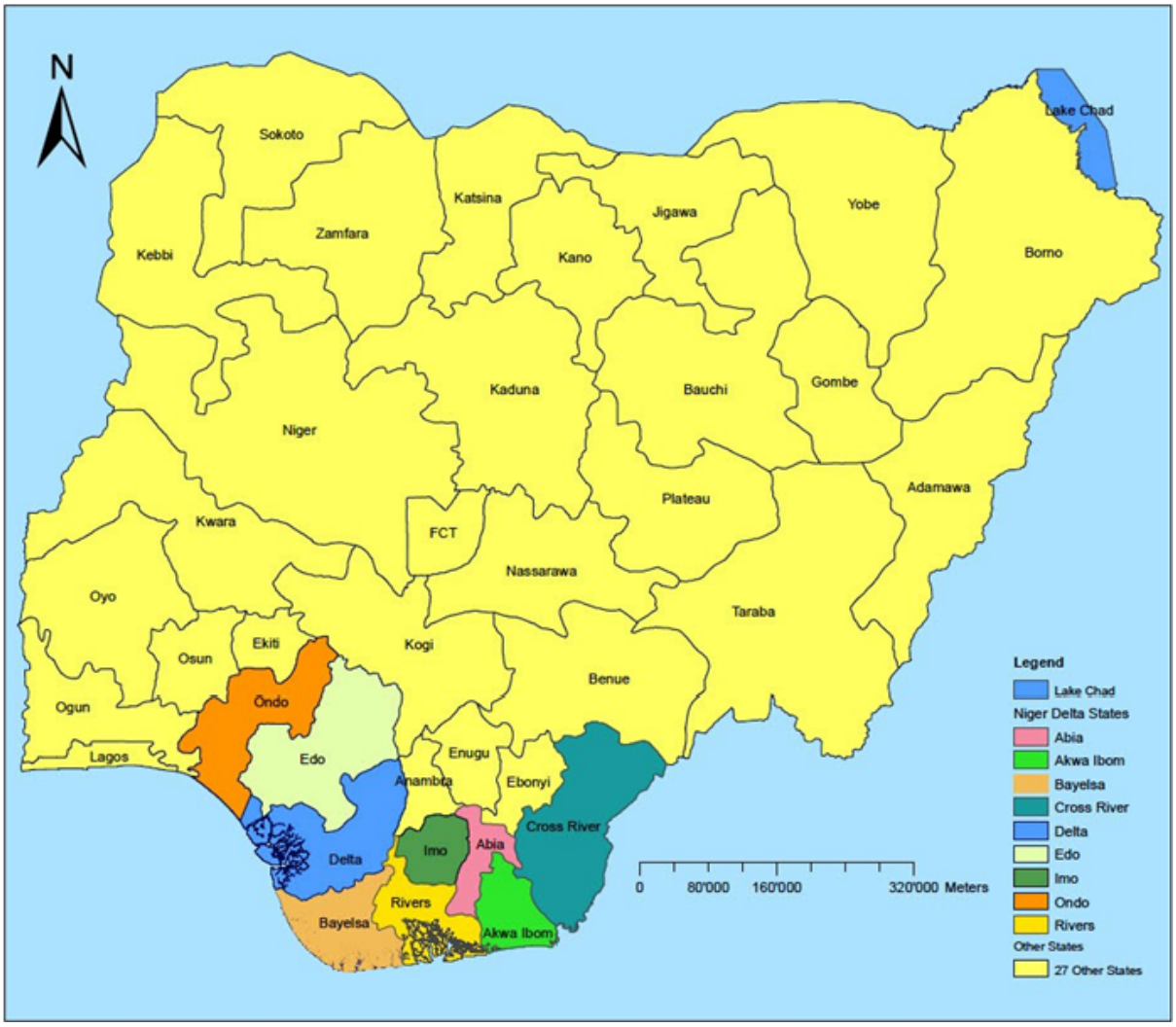

Figure 1. States of the Niger Delta Region (Ite et al. 2013).

The impact of air pollution on human health in Nigeria is well recognized and has received a good level of attention in research and official policy documents (Urhie et al. 2020; Urhie et al. 2017; Usman et al. 2019; Whyte et al. 2020) but the same cannot be said of air pollution's impact on ecosystem health and climate change. This work, therefore, draws these important connections. The attention accorded to air pollution in policy documents could be said to exist only on paper as putting the policies to work has not taken off as is the case with many other policies in the country.

This work brings novelty by exploring the nexus between air pollution and climate change in the Niger Delta area of Nigeria and analyzing them with an environmental justice (EJ) lens. It identifies the major sources of air pollution in the region and highlights the connection to climate change and ecosystem health. EJ is chosen as a theoretical lens due to it being an integral component of the struggle to enhance and sustain a healthy and clean

environment, particularly for people who have traditionally lived and worked closest to pollution sources. It is thus very relevant for this work that focuses on the deprived and marginalized Niger Delta.

1.1. The Niger Delta Area of Nigeria

Nigeria's Niger Delta region (see Figure 1) has been labelled as one of the most polluted spots on Earth (Mbachu 2020). It lies on the Atlantic Coast of southern Nigeria where the River Niger divides into numerous tributaries (Ighedosa 2019). It is the second largest delta in the world, with a coastline spanning approximately 450 km. It covers an estimated area of 110,445.98 km^2 and is the largest and richest wetland in Africa, among the three largest on Earth (Fagbeja et al. 2008; Uyigue and Agho 2007).

The ecosystem of the Niger Delta is very diverse and supports numerous aquatic and terrestrial flora and fauna. It is the most ecologically diverse part of Nigeria being home to the mangrove forests, which are very important but threatened coastal ecosystems (Onyena and Sam 2020). Its different ecological zones comprise: coastal inland zone, freshwater water zone, mangrove swamp zone, and lowland rainforest zone (Chijioke et al. 2018; Uyigue and Agho 2007). The ecosystem services provided by the Niger Delta wetlands are enormous, the most relevant to mitigating climate change being its function as a carbon sink and carbon sequestration. These services, which could be said to serve as a means to the end of human well-being (Costanza 2016), become impaired.

The Niger Delta is home to a wide-ranging species of fish providing food, traditional plants, medicine, and coastal stabilization. However, this ecosystem suffers continuous depletion and degradation, and air pollution is a serious threat. While air pollution constitutes one of the major environmental challenges confronting the region, information on this as it relates to climate change and ecosystem health remains sparse with little data available. There are no monitoring stations or comprehensive databases on air pollution in the region (Ana 2011; Eduk 2017).

Nigeria's position as the largest oil producer in Africa and the sixth largest in the world is due to the oil and gas reserves of its Niger Delta region (Onyena and Sam 2020). The country's entire economy is heavily dependent on the oil and gas reserves of this region, which make up 95% of foreign exchange earnings and up to 83% of the National revenue (Collins 2018; Onyena and Sam 2020).

1.2. Climate Change, Air Pollution, and Ecosystem Health in the Niger Delta

Ecosystem health does not have a simple definition as it is a comprehensive concept that deals with the intricacy of human-environmental systems as well as the many contemporary environmental issues that jeopardize the availability of both ecosystem services and people's wellbeing (Kruse 2019). It encompasses the sustenance of human communities, human and animal health, economic opportunities, and the overall biological functions of ecosystems (Rapport et al. 2001). The need for a vibrant and healthy ecosystem to supply the services the natural and human environment needs cannot be overemphasized. There are interactions and feedbacks between air pollution as a driver of environmental change, climate change and overall ecosystem health. Air pollution and climate change are interlinked via complex interactions in the atmosphere.

The case of the Niger Delta is particularly pertinent due to the sensitiveness of the region and the high dependence of the indigenes on their land and water, which is increasingly threatened as pollution rises and the climate further changes. The associated activities of oil and gas production in the region have seen its atmosphere become the primary sink where the resultant polluting emissions are deposited (Ede and Edokpa 2015). The climate is a fundamental element of the environment whereby a change in the climate causes a change or distortion in the environment and the entire ecosystem (Uyigue and Agho 2007). In a particularly destructive feedback loop, air pollution contributes to climate change and is also aggravated by it. The high levels of active climate pollutants released into the atmosphere, such as methane and carbon dioxide, mainly as a result of anthropogenic activities

cause an energy imbalance between the atmosphere and the Earth's surface. The result is a change in temperature that interferes with the atmosphere's normal chemical composition.

Air pollutants interact with the atmosphere, causing warming and subsequently, environmental degradation and climate change. Combustion of fossil fuels contributes to greenhouse gas emissions, which cause climate change. Climate change contributes to wildfires, which are becoming more frequent and severe, by creating higher temperatures that make more dry fuel available to burn. This leads to more persistent hot and dry fire weather that enables fires to intensify and spread (Pausas and Keeley 2021). We then have a cycle where climate influence fire and fire activity go on to influence climate change by releasing more pollutants into the air (Flannigan et al. 2000).

Black carbon and soot are air pollutants produced from the incomplete combustion of fossil fuel and biomass in the absence of oxygen (Shrestha et al. 2010). They are ever-present in the atmosphere of the Niger Delta (Zabbey et al. 2021b). Black Carbon is known to affect the hygroscopicity (the ability of a material take in moisture from the surrounding environment) of cloud condensation nuclei. This, in turn, affects atmospheric stability, heating, circulation, cloud albedo, and energy balance (Weli et al. 2018). Black carbon emissions are the second-highest contribution to global warming after carbon dioxide emissions (Ramanathan and Carmichael 2008).

In a study by Oloyede and Ede (2020) to determine concentrations and profiles of polycyclic aromatic hydrocarbons (PAHs) in air samples in a Niger Delta city, findings showed that these compounds in air attributed to soot are mainly from pyrogenic sources associated with petroleum combustion (crude oil, biomass, liquid fossil fuel, and automobile combustion). A smaller proportion was due to petrogenic (petroleum) emissions. In their research, they found that the levels of lower molecular weight (LMW) PAHs (2–3 ring PAHs) ranged from 0 to 3961.3 mg/kg with a mean concentration of 511.74 mg/kg in the rainy season, while the levels of LMW PAHs during the dry season ranged from 0.12 to 7.87 mg/kg with a mean concentration of 1.92 mg/kg. The high molecular weight (HMW) PAHs made up 45% of total PAHs in the rainy season and 91% of total PAHs in the dry season from pyrolytic sources with the rest being petrogenic. These concentrations of soot PAHs were higher than the European Commission's guidelines of 1 ng/m3 per year (European Commission 2008) an indicator of the pervasive air pollution the region is known for. The impact of this ubiquitous soot dispersed by air on the ecosystem is wide-ranging. When it settles on water, it interferes with the dissolution of atmospheric oxygen, which impacts circulation and limits the oxygen supply to aquatic organisms. It also interferes with light penetration in water impacting the photosynthetic activities of primary producers, such as phytoplankton. There is also an impact on benthic organisms and consequently the food web and ecosystem balance. When soot is deposited on the respiratory structures of mangroves (pneumatophores and prop roots), it creates stress with adverse effects by limiting oxygen transfer killing off the eggs and larvae of fauna (Babcock-Adams et al. 2017; Nwipie et al. 2019; Zabbey et al. 2021b). The common air pollutants associated with smog and acid rain, namely nitrogen oxides, volatile organic compounds, sulfur oxides, and particulate matter are all released by the petroleum industries of the Niger Delta. These go into the air, undergo atmospheric reactions, and are released back into the ecosystem as acid rain impacting soil, water bodies, and plants. The results include but are not limited to more acidic soils and streams, soil nutrient depletion, changes in nutrient balance in the coastal environment, and disruption in ecosystem diversity (Ede 1998). GHGs trap heat that would otherwise escape into space from the atmosphere, thereby warming the planet due to a rise in temperature (Kweku et al. 2017).

Rising temperatures have impacts on health, agriculture, and biodiversity. The planting season changes as a result, and there are links to increased incidence of diseases and pests (Elum et al. 2016). This worsens the high food insecurity in the region. Anthropogenic emissions of aerosols and aerosol precursor gases from all the activities also affect the seasonality and amount of rainfall (Knippertz et al. 2015). Changes in rainfall patterns could cause flooding or drought (Echendu 2022a; Elum et al. 2016). Notably, the location of

the Niger Delta predisposes it to climate vulnerabilities, such as floods, which are set to rise due to climate change (Echendu and Georgeou 2021; Ehendu 2021; Mmom and Aifesehi 2013; Week and Hanachor 2020).

Climate change on its part increases the production of allergenic air pollutants, such as pollen (due to an extended pollen season) and mold (due to humid conditions caused by extreme weather and associated events, such as flooding). Climate change associated with higher temperatures can also lead to an increase in surface ozone, which is a harmful air pollutant that has been linked to functional, morphologic, biochemical, and immunological disorders (Manisalidis et al. 2020). This occurs due to warmer atmospheric conditions that favor ground-level ozone or smog formation (Geddes and Murphy 2012; Zhang et al. 2019). High ozone concentrations also lead to lower crop yields by inhibiting the breathing capability of plants, slowing down photosynthesis and causing plants to be more prone to diseases (Xu et al. 2019).

The connection between air pollution and mangrove ecosystem depletion and climate change cannot be extricated with its attendant social and economic interactions and impact (Primavera et al. 2019). The capacity of mangrove forests to sequester carbon and reduce greenhouse gases is well established (Hori et al. 2019; Ray and Jana 2017). They store up to five times more carbon per hectare than many other tropical forests around the globe (Friess 2016). The carbon composition of mangroves soils alone is more than the combined biomass and soil of most tropical forests (Onyena and Sam 2020). The loss of the Niger Delta mangroves releases all the carbon it sequesters into the atmosphere, causing atmospheric warming and climate change. This in turn fosters the presence of dangerous air pollutants, such as ozone in a feedback loop. The warmer atmosphere dries the wet soil of the mangroves/wetlands further, releasing even more carbon into the atmosphere. On a global scale, it is estimated that between 150 million to 1 billion tons of CO_2 are emitted annually due to the destruction/loss of mangrove forests (Onyena and Sam 2020). It is thus reasonable to allude that a significant portion of this emission can be attributed to the loss of the Niger Delta Mangrove given that it is being significantly depleted. The very essential role mangroves play in our ecosystem cannot be overemphasized. Its depletion due to human activities in the Niger Delta area where it is a central part of the ecosystem and its impact on climate change deserves urgent attention.

1.3. Environmental Injustice and the Wicked Problem of Air Pollution in the Niger Delta

The environmental justice (EJ) movement was birthed in the United States as a response to the uneven and racially motivated siting of hazardous waste facilities and disposal in poor and disadvantaged black neighborhoods (Banzhaf et al. 2019; Brulle and Pellow 2006). Early work on EJ, therefore, focused on the disproportionate spatial distribution and disposal of environmental waste in predominantly poor and racial minority communities with little political power. Over the years, the concept has evolved to encompass issues not specific to hazardous waste siting. It is increasingly being adopted in studies focusing on various socio-environmental issues due to its broadness and the possibility of integrating new theoretical concepts (Svarstad and Benjaminsen 2020). Today, it is best understood as an enveloping concept that brings social justice considerations to the fore of environmental issues and decision-making. EJ maintains that environmental issues cannot be compartmentalized in silos separate from the political and social milieu (Ali 2006). It is often defined in terms of the distribution or apportionment or non-apportionment of environmental 'goods' and 'bads' (Schlosberg and Carruthers 2010). EJ issues encompass air and water pollution, access to basic needs, unsafe homes, the environment (the surroundings or conditions in which a person lives), etc. EJ is a key part of the battle to enhance and maintain a healthy and clean environment for humans and other living things. Its core principle is that all people and communities have the right to equal protection of environmental and public health regulations and laws (Bullard 1996). There are various classifications of EJ, viz: procedural, precautionary, distributive, and intergenerational (Ikeme 2003; Levenda et al. 2021; Winter 2020). Precautionary EJ hinges on the premise that the unknowns in terms of

short or long-term environmental impact due to the environmental deterioration in human communities necessitate decisions to prevent harm to humans. Procedural justice is the degree to which the public is empowered and involved in decision-making in environmental processes. Distributive justice entails equitable allocation of both the environmental risks and benefits across geographies and demographics. Intergenerational justice relates to sustainability and refers to the obligation and responsibility of the current generation to maintain and assure a safe and healthy environment for the future generation (Bell 2004; Hiskes 2006).

According to Agyeman et al. (2002, p. 77) 'Wherever in the world environmental despoliation and degradation is happening, they are almost always linked to questions of social justice, equity, rights and people's quality of life in its widest sense'. There is nowhere this resonates more than in the Niger Delta area of Nigeria, infamous for the level of ongoing environmental justice and pollution issues. Indigenes lament that they do not reap the benefits of the oil wealth in their land (Nwakanma and Joab-Peterside 2020; Orogun 2010). The many levels of deprivation experienced by the indigenes of the Niger Delta is a classic case of environmental injustice. The disproportionately high burden of air, land, and water pollution in the region in comparison to other parts of the country is well documented (Babatunde et al. 2018; Boris 2015; Ede 1998; Paki and Tano 2018; Umukoro 2018; Yakubu 2018; Zabbey et al. 2021a). The irony, in this case, is that while the region lays the golden egg for the Nigerian government or is a source of national 'good', they have received in return only environmental 'bads'. It remains an underdeveloped and deprived region (Collins 2018; Elum et al. 2016; Ikelegbe 2001). As a push back to the 'bads' they are left with, these coastal communities that depend on their ecosystem for survival but which can no longer sustain them take to 'illegal' extraction and refining of oil (Ikelegbe 2005; Onyena and Sam 2020). In this work, we adopt the use of the term 'artisanal refining' in lieu of 'illegal refining' because of the debates and conflicts surrounding the extraction of this resource found on their land for survival, whereby it is deemed rightfully legitimate in some quarters and illegal in others (Amah 2020; Ebeku 2002; Ejobowah 2000; Ikelegbe 2005; Niworu 2017; Ntor 2020; Okwelum 2021). There is the view that artisanal refiners are left with no options after the destruction of farming and fishing activities by oil exploration activities (Umukoro 2018).

This act of oil extraction by locals, therefore, becomes a wicked problem whereby their processes of extraction further result in air pollution degrading the ecosystem further. Meanwhile, many of the artisanal refiners see it as their only way of earning income due to the high level of unemployment and poverty, and they continue with their refining activity despite the overall negative impact on the ecosystem. This continues cyclically. Locals taking to artisanal refining is a form of resistance and an attempt to achieve distributive justice under the surmise of taking what rightfully belongs to them and surviving off their ancestral land.

This issue of marginalization and deprivation is not limited to Nigeria as Torras and Boyce (1998) find that on a global scale, nations with greater civil and political rights, better income distribution, and higher literacy rates tend to have a better environmental quality than those with more uneven income distributions, fewer rights, and lower literacy levels (measured by concentrations of water and air pollutants, access to clean water and sanitation). Environmental problems disproportionately impact the poor who are less able to avoid the emissions from motor vehicle exhausts, polluting industries, and power generation. Most times, they must earn their living amid pollution. Unequal distribution of environmental 'bads' is compounded by the fact that, globally, nationally, and locally in the case of the Niger Delta, the poor are not the major polluters. The main culprits of environmental pollution and degradation are the wealthy and powerful multinational Western-owned oil corporations operating in the region (Ejiba et al. 2016). Their levels of emissions in Nigeria breach regulations (Ite et al. 2013), and they cannot get away with such actions in their countries of origin. In the end, more than 75% of the people who depend on their environment for livelihood suffer even more deprivation (Babatunde 2020).

The identification of air pollution as the major problem in the Niger Delta (Ana 2011), with evidence of connections between this problem and deprivation, is an issue of environmental justice. Adopting the EJ lens enables a better understanding of the complexities surrounding air pollution, which can help to inform sustainable mitigation approaches.

1.4. Major Sources of Air Pollution in the Niger Delta

The sources of air pollution in the Niger Delta region are mainly anthropogenic. Air pollutants comprise not just greenhouse gases (principally carbon dioxide, methane, nitrous oxide, and others) but also particulate matter, which ends up dispersing all over the globe, including even into the remote polar regions. Ite et al. (2013) classify atmospheric pollutants into (i) particulate matter, (ii) persistent organic pollutants, (iii) gaseous pollutants, and (iv) heavy metals and/or trace elements.

There exists research focused on some parts of the Niger Delta on pollutants (Agbozu and Oghama 2021; Eduk 2017; Ibe et al. 2020; Onakpohor et al. 2020). However, the levels of pollution from various sources cannot be holistically ascertained. This is due to the absence of a focused or systematic monitoring system for the numerous pollutants emanating from various sources. Therefore, there is no continuous data pool available (Okedere et al. 2021). In this section, we discuss the common sources of air pollution in the Niger Delta region.

1.4.1. Gas Flaring

Gas flaring is a major source of pollution in the Niger Delta. It is the rapid oxidation or burning of crude oil-associated natural gas that releases gaseous, particulate, and heat matter into the atmosphere with negative impacts on ecosystem health (Edino et al. 2010; Giwa et al. 2019). Flared gas is a principal contributor to global warming and climate change as it is a source of GHG, volatile organic compounds, precursor gases, toxins (inclusive of benzene, hydrogen sulfide, toluene, etc.), and black carbon, which are all dangerous pollutants that cause ecological degradation and destruction (Fawole et al. 2016; Giwa et al. 2014; Giwa et al. 2019; Ubani and Onyejekwe 2013; Yaduma et al. 2013).

The resultant air pollutants from gas flaring cause ecological degradation by negatively impacting the quality of soil and water resources via precipitation. A chain reaction occurs whereby pollution of the atmosphere results in polluted precipitation seeping into soils and water bodies. Some of these pollutants are also released back into the atmosphere. Acid rain, a common result of polluted air alters the soil chemistry consequently affecting plant growth and water quality in many ways. This has been experienced in the Niger Delta, where activities such as water collection during rainfall can no longer be safely carried out due to the resultant polluted rainwater (Imarhiagbe and Osarenotor 2020). Land-based activities, such as agriculture, can no longer sufficiently provide for people due to the reduced yield from soil polluted by acid rain (Akpan and Bassey 2020; Seiyaboh and Izah 2019). This is a serious concern as water bodies and soil are the bedrock of all forms of life on Earth, providing habitats, elements, nutrients, and minerals necessary for biological activities.

Gas flaring is a colossal waste of natural resources, especially in light of the local demand–supply gap, where the volume of gas flared exceeds the domestic sales (also in the international gas market). However, it remains the practice today (Okoro et al. 2021). This is despite the action being a key contributory factor to destroying, impoverishing, and degrading the region's ecosystem. The amount of gas flared daily in the Niger Delta is much more than the total energy needs of sub-Saharan Africa (Oni and Oyewo 2011). In 2014, Nigeria ranked fifth globally among the gas flaring countries, an improvement as it has consistently ranked second place for three decades (Giwa et al. 2019; USEIA 2016). In 1970, 99% of gas produced was flared. This dropped to 51% in 2001 but rose again to 53% in 2002 (Fagbeja et al. 2008). The Nigerian government made efforts at utilizing the associated gas by developing a liquefied natural gas (LNG) plant in Bonny. The gas flared dropped to approximately 39% of the total gas produced in 2004/2005 (NBS 2006). In 2018, it was reported that only 10% of associated gas produced was flared, having been on a steady

decline since 2002 (PWC 2019). This would have represented a significant improvement in the oil and gas sector. However, there are contrary reports, with monitoring conducted from 2012 having the same year 2018 as the year with the most gas flared (Chimezie 2020). This would imply the practice is worsening instead of abating. This underlines that despite positive figures mostly from official government sources, there may be a need to remain skeptical at taking these values at face value due to the inconsistencies in reporting and overall graft in the system. The country's commitment to phasing out gas flaring is questionable as evidenced by the recurrent shift of the dates to end gas flaring. Gas flaring was originally outlawed in 1984 but dates to end flaring have changed many times over the years, with the most recent timeline being 2030 (Okoro et al. 2021; Zabbey et al. 2021b).

1.4.2. Fossil Fuel-Burning

Nigeria is a major fossil fuel user in Africa. CO_2 is the most potent/common greenhouse gas(GHG), primarily resulting from the burning of fossil fuels (Elum et al. 2017). The most $C0_2$ emissions in Nigeria emanate from the Niger Delta (Doumbia et al. 2019). Due to poverty and lack of infrastructural facilities for providing clean energy to homes, the use of firewood and kerosene for domestic cooking and lighting is the norm in the Niger Delta region and other parts of the country. Smoke from traditional biomass and firewood cause over 95,000 annual deaths in Nigeria (Akomolafe and Ogunleye 2017). The burning of biomass, such as firewood, causes air pollution and emits carbonaceous aerosols, which have a forceful radiative effect (Knippertz et al. 2015). Aerosols generally affect the climate due to their impact on radiation and clouds. These aerosols are also oxides of nitrogen, volatile organic compounds, and carbon monoxide, among others, which impact the climate by disturbing ozone and methane concentrations and by creating secondary aerosol particles (Knippertz et al. 2015). Power plants and heavy industrial equipment, such as coolants, separators, boilers, and burners burn/use fossil fuels. Industries, such as foundries, construction, and automobile, are also significant emitters of GHGs and contribute to the poor air quality of the Niger Delta (Yakubu 2018). The country's electricity supply is among the worst in the world with a huge deficit in demand despite it being rich in energy sources (Momoh et al. 2018; Oyedepo et al. 2018). Power is erratic and unreliable, leading to increased reliance on petrol and diesel generators with their attendant air-polluting emissions, which contribute to climate change (Akinyele 2018). Affordable and clean energy is pertinent for sustainable development (Baiyegunhi and Hassan 2014). This need becomes even more critical in ecologically sensitive regions, such as the Niger Delta.

Access to cleaner forms of energy at the individual level is marred by high poverty levels. The prices of the most common clean alternative, Liquified Petroleum Gas(LPG), are not affordable to the majority of the populace (Ozoh et al. 2018). However, citizens overall express a willingness to switch to cleaner forms of energy (Onyekuru et al. 2020; Ozier et al. 2018; Ozoh et al. 2018). The government has a central role in promoting uptake and access to cleaner energy for domestic use. Investing in the clean energy sector, especially for cooking is paramount to reducing air pollution and associated impacts. Subsidizing its use for the wider populace is crucial. This is because affordability will play a key role in the final adoption mostly among the poorer rural households. Organizations such as the Nigerian Alliance for Clean Cook Stoves launched in 2011, a public-private partnership seeking to introduce 10 million clean cookstoves to the Nigerian market by 2021, are already at the frontlines of fast-tracking the adoption of cleaner energy for domestic use. More support and capacity enhancement are necessary to support such sustainable energy transition initiatives.

Harnessing just the gas flared in the region could provide millions of Nigerians with electricity and cleaner power. However, there has been little commitment on the part of the government to harness this energy source. The requisite technology to commercialize the flared gas is capital-intensive but the Nigerian government is known to have backed down financially on occasions that investors have expressed interest in rolling out the technology

in partnership with the federal government (Ojewale 2021). With sufficient affordability, availability of clean energy sources, and education, chances are high that the people would willingly transition to cleaner sustainable energy sources.

1.4.3. Artisanal Refining of Crude Oil

The Niger Delta region has a vibrant artisanal refining sector that operates outside the law and contributes significantly to air pollution (Onakpohor et al. 2020; Onuh et al. 2021). Artisanal refining of crude oil involves a simple technology employing a local distillery method and subjecting the distilleries to heat from an open fire to yield refined diesel, petrol, and kerosene (Onakpohor et al. 2020). The materials utilized are locally acquired and constructed comprising drums, pipes, drilling machines, Cotonou boats, firewood, pumping machines, crude oil, etc. The process requires little set-up capital and a few personnel. During the refining process, two drums of crude oil produce one drum of refined product meaning that half of the original quantity becomes some form of waste that is released into the environment. Calculating this resultant waste from artisanal refining in terms of the daily production in the region gives a picture of the volume of ecological waste and air pollution that could lead to irreversible ecosystem damage and changes (Babatunde et al. 2018). The distilleries are heated on open fires that are fed by crude oil, resulting in the release of thick fumes and smoke into the atmosphere (Onakpohor et al. 2020). For a more in-depth overview of the refining process, see Onakpohor et al. (2020). The environmental impacts of this refining activity, part of much larger 'illegal bunkering' operations, are numerous ranging from health impacts to wider ecosystem pollution (Obenade and Amangabara 2014). The country is believed to lose approximately 300,000 to 400,000 barrels of oil daily to bunkering activities (Boris 2015; Michael and Joepen 2021). However, these are only estimates as the actual figures are unknown. As this activity is illegal, the preferred action of the Joint Task Force (JTF) law enforcement agents (JTF comprises the Navy, Army, and paramilitary agencies) is burning of the refining facilities, which releases further pollutants into the air. The JTF leadership has lamented on different occasions that they do not have the resources or capacity to do anything else other than burning the facilities. There have also been claims of the JTF and other powerful non-indigenes engaging in bunkering activities themselves worsening the pollution problem (Paki and Tano 2018). The level and proliferation of artisanal refining show no signs of ebbing with the environment being the worse-off for it.

1.4.4. Transportation

Transportation in the Niger Delta is another major source of air pollution in the region. The huge deficit in transportation infrastructure has made road congestion a hallmark in the bigger cities of the Niger Delta. The population of the region is approximately 31 million (Boris 2015). This number is set to rise with the overall growing urbanization rate of the country (Ehendu 2020b). The perceived abundant economic opportunities in the region due to its status as the oil hub of the country attracts many migrants from other parts of the country who have a vision of accessing better economic opportunities and standards of living. This increased urbanization and population growth brings with it many challenges, including air pollution due to increased industrial and transportation activities (Verla et al. 2017). African urban centers are particularly known to have higher levels of pollution due to the reliance on road transport to move goods and people (Echendu and Okafor 2021). The more populated the region, the more air pollution due to the higher number of vehicles. Most of these vehicles are old and emit more pollutants. The hallmark poor state of the roads also means people spend longer on commutes leading to even more air pollution. This is because the longer the vehicles have to stay on the roads, the more pollutants they emit. In a study assessing pollutants from heavy traffic in Port Harcourt, a major city in the Niger Delta, very high levels of gaseous pollutants were found. These pollutants were at levels far exceeding the guidelines of the Federal Ministry of Environment. Specifically, the concentrations of Carbon Monoxide(CO), Nitrogen Dioxide(NO_2), Sulphur Dioxide(SO_2)

and hydrocarbons were all above permissible levels (Okonkwo et al. 2014). The significant level of air pollution resulting from transportation in the region cannot be ignored.

1.5. Current Pollution Control Legislation and Shortcomings

The Federal Environmental Protection Agency (FEPA) was the original body responsible for implementing strategies for controlling air quality. FEPA was originally established under the Amended decree No. 59 of 1992 in the Laws of the Federation of Nigeria to undertake the following but not limited tasks:

- Preparing a comprehensive national policy for the protection of the environment and conservation of natural resources, including procedures for environmental impact assessment for all development projects;
- Preparing periodic master plans for the development of environmental sciences and technology with similar bodies in other countries and with international bodies connected with the protection of the environment and the conservation of natural resources;
- Co-operating with federal and state ministries, local governments, statutory bodies, and research agencies on matters and facilities relating to the protection of the environment and the conservation of natural resources.

Constitutional changes in 1999 replaced FEPA with the Federal Ministry of Environment (FME), which took over its functions and is the central regulator and administrator of environmental laws in Nigeria today (Yakubu 2018). These institutional and legislative frameworks for controlling air pollution were deemed too limited and inconsistent to manage contemporary problems of air pollution. They were also critiqued as focusing mainly on the oil and gas industry without consideration for other pollution sources (Olowoporoku et al. 2011). In 2007, the National Environmental Standards and Regulation Enforcement Agency (NESREA) Act replaced the FEPA Act (Federal Government of Nigeria 2007). The NESREA Act mandates the agency to create and revise air quality laws and oversee the control of harmful substances on land, air, and sea asides from activities emanating from the oil and gas industries. Improved air quality became one of the core environmental priorities of NESREA's corporate vision (Olowoporoku et al. 2011). In addition to the proscription of hazardous emissions into the atmosphere, industries are also mandated to report to NESREA if any emissions occur and submit a detailed list of chemicals used in production and to also identify hazardous substances that constitute a threat to the environment (Yakubu 2018). The emergence of NESREA was seen as a positive shift from the lukewarm attitude on air quality management of previous governments (Olowoporoku et al. 2011).

As evidenced by when these pollution-specific legislations first came into force, the oil industry in the Niger Delta, being the main source of pollution in the region (Babatunde et al. 2019), operated for decades with little to no effective monitoring. Nigeria's law on oil operations mandates the oil firms to comply with 'good oil field practice' and internationally recognized standards (American Petroleum Institute and American Society of Mechanical Engineering Standards) but this is not the reality on the ground (Amnesty 2009). Nigeria's laws are deficient in relation to overall environmental pollution by oil firms and its impact on the overall ecosystem. Failure to enforce laws has been attributed to the country being a partner and a major financial beneficiary in oil operations leading to a conflict of interest. There is also a lack of capacity and confusion among the regulatory bodies and agencies who work at cross-purposes, and under-resourcing of the environmental regulatory bodies (Amnesty 2009; Olujobi 2021). An example of confusion within the regulatory parameters is the Act establishing NESREA that explicitly bars it from enforcing compliance in the oil and gas sector. This means that the agency can set guidelines but cannot do much to ensure compliance. A different agency is tasked specifically with monitoring the activities of the oil and gas sector. What is obtainable in practice is that the companies are mandated to do their own monitoring on pollution control and report to government authorities, but they are not subject to any independent oversight to ensure accuracy. A lack of basic operational resources (laboratories to carry out analysis, vehicles to visit sites, etc.) for the agencies

to carry out their work has been reported (Amnesty 2009). The associated sanctions on pollution in the environmental legislation have failed as a deterrent (Olujobi and Olusola-Olujobi 2019). This is because the financial amounts are so paltry that the major polluters who are rich multinationals are better off paying the fines than seeking sustainable measures to combat air pollution. The lack of systematic monitoring of pollutants makes it even harder to ascribe blame to defaulters. Weak articulation and enforcement is another reason for failures in pollution control (Olujobi and Olusola-Olujobi 2020). To make progress, it is necessary to review these laws and work out effective enforcement modalities.

1.6. Action Framework for Mitigating Pollution and Recommendations

The different sources and levels that result in air pollution require concerted actions at these various levels. This section recommends actions that can be taken to help to control the menace of air pollution in the Niger Delta. Some of these measures, such as improvement in transport infrastructure, including road design and maintenance, would require substantial financial investment in the sector. However, Nigeria has the financial muscle to achieve this—being the largest economy in Africa (Echendu 2022b), the 29th largest globally, and one of the fastest emerging economies in the world. Table 1 is a proposed action framework to mitigate air pollution in the region.

Table 1. Action Framework for Air pollution mitigation in the Niger Delta.

I	**Individual/ Community**	• Avoid burning wood for domestic fuel as climate active pollutants are released during the process; • Adopt cleaner energy sources for domestic use; • Use public transport services as an alternative to private transportation to minimize emissions; • Reduce waste generation which leads to open waste burning in the community.
L	**Local Government**	• Create and enforce local clean air policies; • Organize regular sensitization programs for the community on environmental issues; • Commence cleanup and restoration of mangroves and wetlands; • Set up local agencies that oversee air pollution mitigation and active monitoring of air quality in the locality; • Create sustainable employment opportunities that would discourage artisanal refining of crude oil; • Improve transport infrastructure including walking; • Provide adequate waste management infrastructure to avoid burning.
S	**State Government**	• Collaborative cooperation with other actors (individual, local, and state governments); • Measure and keep records of air pollution and GHGs concentrations on a consistent basis to inform action; • Improve road transport infrastructure; • Invest in research and roll-out of cleaner energy sources; • Foster research and development for technological solutions that abate air pollutants in the country; • Make necessary budgetary provisions for air pollution mitigation projects and employment creation projects.
F	**Federal Government**	• Improve transport infrastructure base to reduce time spent by vehicles on congested roads; • Put an end to the incessant postponing of dates to end gas flaring in the country; • Review air pollution laws in line with current international requirements and work out effective enforcement modalities; • Establish facilities and funding for regular air quality assessment via air sampling and monitoring in the state; • Conduct intensive environmental research to improve data availability and restore and conserve wetlands and mangroves; • Keep air quality records and develop an air quality management database for the state; • Ensure funds are available to the local government for air pollution and climate change mitigation activities; • Work collaboratively with other air management stakeholders at the local, national and international levels; • Invest in research and roll-out of cleaner energy resources; • Active collaboration with the state and local governments on air pollution measures and strategies.

2. Conclusions

The Niger Delta region is a sensitive and unique ecosystem seriously threatened by the impacts of pollution. The beneficial ecosystem functions provided by this unique region are continuously being threatened by air pollution. The unusually high levels of air pollution in the region due to mainly oil extraction activities and fossil fuel burning has plunged the region into a cyclical level of degradation. There seems to be no end in sight due to insufficient action by the relevant stakeholders. The pollution problems are also an issue of environmental justice as the Indigenous peoples of the land are being deprived of their ancestral lands and waters, which are their primary means of sustenance. This is due to the interactions between air pollution, climate change, and ecosystem health, which have led to further degradation of a region that has suffered substantial decline since the beginning of oil exploration. Undoubtedly, air pollution and the emissions that contribute to climate change have implications for overall ecosystem health. The global climate burden emanating from developing countries pales in comparison to the global north, but serious action is still needed to mitigate pollution in developing countries because the impacts have negative effects both locally and globally. This work has drawn attention to the air pollution in the region and showcased how the impacts push the region further into poverty. The residents taking to artisanal refining of crude oil as a means of survival further contribute to air pollution which goes on to have cascading effects leading to further deprivation. All relevant stakeholders need to work together to curtail the problem of air pollution for a more sustainable Niger Delta. The key role its ecosystem plays in climate change mitigation makes this imperative. Local policies need to come into place which should be geared toward resolving both local and global environmental issues. Decision-makers need to adopt an approach that will satisfactorily address the environmental justice concerns that further perpetuate pollution and urgently bring an end to the gas flaring that is the norm rather than an exception in the region. Concerted and committed action by all stakeholders can improve the ecosystem of the Niger Delta region of Nigeria.

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