Air Pollution Interconnections with Climate and Environmental Health

Subjects: Area Studies

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Air pollution is a major environmental problem. It is a problem that is interconnected with climate change and ecosystem health. The dynamics within the Niger Delta region of Nigeria are discovered. The high reliance of the people of the Niger Delta on their environment increases their vulnerability to environmental changes. This makes the problem an issue of environmental Justice when the drivers of air pollution in the region are factored in. Urgent and concerted action is required at the individual, local and national levels. The directions in this regard are highlighted. The emission and transmission of air pollutants cause air pollution. Nigeria, Africa's most populous nation of over 200 million, 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.

Keywords: action framework ; air pollution ; Niger Delta ; Environmetal Justice ; ecosystem health ; air pollution and climate change

1. 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 and emissions from the oil and gas production in the region have further polluted its atmosphere (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). Researchers 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; Echendu 2021; Mmom and Aifesehi 2013; Week and Wizor 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.

2. 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.

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, researchers discuss the common sources of air pollution in the Niger Delta region.

2.1. 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).

2.2. 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.

2.3. 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).

2.4. 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 (Echendu 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.

3. 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.

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