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Slow death from pollution: potential health hazards from air quality in the mgbede oil fields of south-south Nigeria

Abstract

Background: Today, pollution is a serious issue that threatens the health of billions of people, weakens the economic security of nations, and is to blame for a significant portion of the world's burden of disease, disability, lost productivity, medical expenses, and costs associated with ecosystem damage and premature death. However, despite their enormous size, these expenses are often hidden and frequently go unnoticed as a result of pollution. This has the effect of preventing the entire costs of pollution from being understood, often going uncounted, and being used to counteract economic arguments which are biased towards pollution control.

Objectives: This study investigated air quality in the Mgbede Oil Fields of South-south Nigeria.

Methods: Air quality sampling points were selected purposefully to meet the objectives of the study. Portable Real-Time Monitoring Technique was used was used for measurement.

Results: From the analysis of air samples, cadmium (0.005-0.008 µg/m^3) and lead (0.012ug/m^3) were detected within the vicinity of the gas flare. Nickel was in the range <0.002 to 0.014 µg/m^3 with highest concentrations in the gas flare area. Total suspended particles were within acceptable limits (120 ug/m^3) in all locations with PM_{10} component above standards in the vicinity of the gas flare (20.6-22.6 ug/m^3). Zinc was in the range <0.002 to 0.014 ug/m^3 with maximum concentrations around the gas flare site. Although these concentrations are well within the acceptable daily exposure range but could be associated with exacerbations in risks of paediatric asthma. NOx ranged between 0.038-0.058 ug/m^3 in the study area and falls above standards (0.04 ug/m^3) in over 80% of sampled locations. Highest concentrations (0.058 ug/m^3) were found around the flare area. SO_2 was only detected at concentrations above acceptable limits within the gas flare site at Ebocha.

Conclusion: The study therefore concluded that air quality in the area is not only negatively influenced by continuous gas flaring but occur at levels above acceptable international standards where environmental health could be adversely affected. Relocation of all homesteads within 1km radius of the gas flare with adequate compensation for inhabitants with improvement in healthcare delivery; and the establishment of a special health insurance trust fund for long-term exposure to pollutants from oil producing activities are among recommendations. Additionally, since this public health issue necessitates environmental health policies to reduce air pollution, efforts to battle the massive air pollution issues in the Niger Delta and its environmental quality must be combined by worldwide mitigation.

Keywords: air pollution, quantified risk factor, environmental health, gas flaring, heavy metals, oxides, paediatric asthma, PAHs

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Introduction

Niger Delta is a major hotspot of health and climate-impacting black carbon (BC) emissions, influencing environmental sustainability in densely populated area. Black carbon, being one of the more health-detrimental components in $PM_{2.5}$, it is the primary environmental factor contributing to human sickness, it presents a significant barrier to sustainable development. It is a major societal issue, a worldwide concern, and a threat multiplier because of how it will be solved and how air pollution will change.[1,2] In Nigeria, there are three main sources of ambient air pollution: the production and usage of energy,[3–5] industry, and transportation, all of which rise with population and economic development. A significant contributing component to all three sources is rapid urbanization. Air pollution in the Niger Delta of Nigeria is mostly caused by mainly oil production related activities including gas flaring, oil well fires and blow outs and most recently by oil theft and illegal and artisanal oil reefing activities. For over 50 years, Nigeria flared about 2.1 billion cubic feet per day (bcf/d) or 92% of its total associated gas production until in 2002 in the Niger Delta when flaring stood at about 76%. This situation has been described as a 'human rights, economic and environmental monstrosity' (Climate Justice Program and Environmental Rights Action, 2005).

According to Ezekwe, Ordinioha and Victor (in press) the environmental problems caused by gas flaring and oil fires are global as well as local. For example, CO_2, methane, NOx, and SO_2 emitted during flaring and venting contribute to increase in the concentration of green-house gases (GHG) in the atmosphere, which in turn cause acid rain and contribute to global warming thereby causing climate change.[1,6,2] This negates commitments made by countries under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. When on the other hand the burning of natural gas occurs near wildlife or inhabited areas, the effects raise potential environmental and health concerns and have been known to cause acid rains and significantly affecting the health of the inhabitants, causing ailments that affect the respiratory, eye, skin, and intestines of people in impacted areas.[7–9,1] Half a century long continuous gas flaring, oil pipeline and storage tank explosions and fires in the Niger Delta apart from contributing to climate change, which has serious implications for both Nigeria and the rest of the world is associated with acid rain formation through emissions of sulphur dioxide (SO_2) and nitrogen oxides (NOx). These combine with atmospheric moisture to form sulphuric and nitric acids respectively and have been associated with destruction of lakes, wetlands, and roofing sheets.[10–12,2] Oxides of Nitrogen, Carbon and Sulphur (NOx, CO_2, CO, SO_2), particulate matter, hydrocarbons, ash, soot, photochemical oxidants, and hydrogen sulphide (H_2S) associated with gas flaring and oil fires also acidify the soil, hence depleting soil nutrient.[13–19] Previous studies have shown that the nutritional values of crops within such vicinity are reduced. In some cases, there is no vegetation in the areas surrounding the flare due partly to the tremendous heat that is produced and acid nature of soil pH.[20–22,9,17]

The Nigerian Agip Oil Co. Ltd. (NAOC) a member of the Italian Eni Group started operations in Nigeria in 1962 and in 1965 the oil fields Ebocha and Mgbede were discovered. In 1970 and 1972, production began at the Ebocha and Mgbede fields. The Ebocha and Mgbede Fields are part of the Oil Mining Lease (OML 61) located onshore, south of OML 60 covering an area of 1,499 km^2 (370,410 acres). Exploration in OML 61 began with the discovery of the Ebocha oil and gas condensate field in 1965.[23,24,17,18] About seven communities are located within the Mgbede Oil Fields (Ebocha, Mgbede, Aggah, Umudike, Okwuzi, Abaezi and Etekwuru) and over 50 years of continuous oil production activities in the study area apart from causing water pollution due to incessant oil leaks,[13–17] oil storage tank blow outs and artisanal oil refining may be contributing highly to climate change (which has serious implications for both Nigeria and the rest of the world) and associated acid rain formation through the emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NOx). These gases combine with atmospheric moisture to form carbonic, sulphuric, and nitric acids respectively and have been associated with destruction of lakes, wetlands, and roofing sheets.[25,10] Oxides of Nitrogen, Carbon and Sulphur (NO_2, CO_2, CO, SO_2), particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulphide (H_2S) associated with gas flaring also acidify the soil, hence depleting soil nutrient.[17,21] Previous studies have shown that the nutritional values of crops within such vicinity are reduced. In some cases, there is no vegetation in the areas surrounding the flare due partly to the tremendous heat that is produced and acid nature of soil pH.[20,21,26,8,11,12,17] Soils of the study area are fast losing their fertility and capacity for sustainable agriculture due to the acidification complicated by high ambient temperatures which leads to stunted growths and the scotched plants effect thereby leading to reducing crops yields and exacerbating hunger.

Adverse health impacts on man include child respiratory illnesses and asthma (which results to premature death), cancer, neurological, reproductive, and developmental impairments, deformities in children, lung damage and skin problems (causing low life expectancy of about 40 years on average in Niger Delta).[27,7,11,9] It is therefore exigent to document air quality in the oil producing areas of Nigeria with a view to identify trends, characteristics, causes, rates and their environmental health impacts. The aim of this study is to report air quality in the communities in the Mgbede Oil Fields of South-south Nigeria, and the study questions that determined the directions of this study will include: Is there any significant difference between air quality in the study area and internationally acceptable standards? How does gas flaring affect air quality in the area? How does air quality in the area affect human health?

Description of study area

The Mgbede Oil Fields fall within the Egbema district of the Ogba/Egbema/Ndoni Local Government Area of Rivers state and the Ohaji/Egbema Local Government Area of Imo State, Nigeria (Figure 1). The Area is host to the Ebocha Oil Centre, and other facilities and firms that service them. Production, processing, and export facilities within OML 61 owned by the NAOC JV include: To date, the License comprises 12 producing fields (Oando Energy Resources, 2014). The Mgbede Oil Fields has Ebocha, Mgbede, Aggah, Umudike, Okwuzi, Abaezi and Etekwuru communities located within it. The study area is located within longitudes N05°.464546 and N05°.447248 and latitudes E006°.687214 and E006°.791868 in both the Ogba/Egbema/Ndoni Local Government Area (ONEIGA) of Rivers State and the Ohaji/Egbema Local Government Area of Imo State and situated within the hydrocarbon asset in OML 61 and OML 20; all located within the Northeast of the Niger Delta region of Nigeria.

Figure 1 Location (Black dot) of study area (adapted from freeworld maps.net, 2022).

Climate, physiography and vegetation

The area is a low-lying deltaic (<25m) tropical rainforest environment According to Nwaogbidi[28] the area is a Tropical rainforest or Equatorial monsoon climate region described in the Köppen climate classification system as "Af". The Tropical rainforest climate is characterized by very high rainfall, temperature, and relative humidity. It is located within a maze of freshwater water swamps, floodplains, and arable land within the Sombreiro-Orashi river interbasinal area. Landuse and land cover in the study area is dominated by farmlands, built up areas and by secondary to riparian rainforests dominated by the raffia palm (Raphia vinifera), while major occupation is an oil dominated economy amidst pockets of traditional farming occupation. The area has a very high commercial presence for a rural area due to the presence of oil producing and servicing organisations giving it the appearance of a bloated and sickly quasi-urban setting.

Materials and methods

The purposive sampling techniques was adopted and used to select sampling sites to suite the research objectives. Air samples were collected at six (6) sites along a trajectory from gas flare site and downwind into the communities (Figures 2). Site A is gas flare point, Site B is 650m upwind at Ndoni road, Site C about 650m

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downwind at Ebocha, Site D about 2.5km from the flare point near Uchenna Hotels Mgbede. Site E and F are located about 4.5km away from the flare point at Aggah and Okwuzi communities respectively. Following the methods described in Ezekwe.[29] One (1) sampling site was taken at 650m from the gas flare point at Ebocha and other points between 2.5 to 5km in the east-northeast and west-northeast direction (at Stonevillage Mgbede, between Mgbede and Aggah, at Etekwuru road Aggah, behind Okwuzi primary school and at Ajakoi community) from the flare stack. Air quality measurements using the Portable Real-Time Monitoring Technique was used. This uses a combination of near surface point of impact analysis and ambient air (outdoor- breathing zone) sampling within specific distances from points of impact (for instance, a gas flare) (USEPA, 2001; 2012; 2014; 2018; 2021) and laboratory methods. Air samples were automatically analysed for Nitrogen oxides (NOx and NO_2), carbon monoxide (CO), Sulphur dioxide (SO_2), VOC and H_2S using the Aeroqual 500™ Gas Monitor while Particulate Matter (PM) was measured using the Kanomax 3900 Particle Counter.

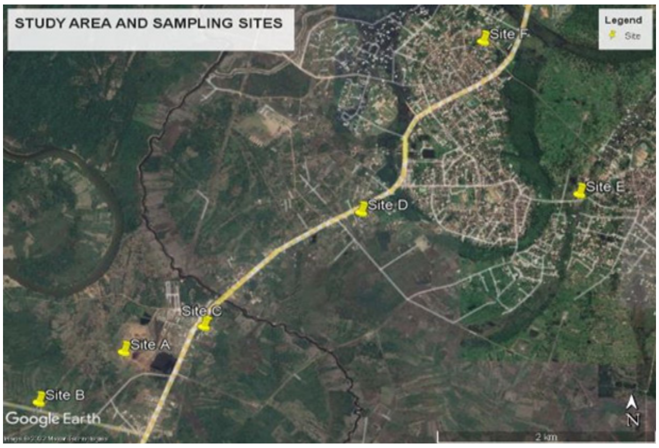

Figure 2 Sampling locations (Adapted from Maxar Technologies, 2022).

Trace metals sampling and analysis

High volume air samplers (Kanomax 3900 Particle Counter) and Membrane filters was used to collect heavy metal concentrates in the air. Collected samples were digested using a mixture of analytical grade nitric acid and analytical grade hydrochloric acid and analysed to evaluate the levels of heavy metals by atomic absorption Spectrophotometry following the ASTM D1971/4691 method. Digestion for the Air Particulate filters was done using ASTM D1914 method. The membrane filter paper was digested completely using 5ml of concentration. HNO_3 and heating using heating mantle. The digest was later hydrolysed with 1ml of 30% H_2O and heated until the effervescence subsides. Finally, the digest was diluted to 100ml prior to being aspirated for heavy metals analyses. The diluted samples were preserved in the refrigerator. The analyses for heavy metals samples were done using Flame Atomic Absorption Spectrophotometer (Shimadzu AA-6650).

Levels of trace metals like Cd, Ni, Pb, and Zn in ambient air was determined using:

$$C = (Ms – Mb) \times Vs \times Fa/V \times Ft$$

Where, C = concentration, µg metal/m^3., Ms = metal concentration µg/mL

Mb = blank concentration µg/mL, Vs = total volume of extraction in mL

Fa = total area of exposed filter in cm^2, V = Volume of air sampled in m3

Ft = Area of filter taken for digestion in cm^2.

Results and discussion

Given that excessive concentrations of air pollutants have been found to generally have negative impacts on human health, the issue of air pollution poses a severe menace to environmental health across many places throughout the world.[8,9,2] One of the major modern killers is air pollution. According to Raimi et al.[8,2] 6.4 million deaths globally occurred in 2015 as a result of air pollution, of which 2.8 million were attributable to indoor air pollution and 4.2 million to outdoor air pollution.[1] In the same year, tobacco contributed to 7 million fatalities,[1,30,31] 1.2 million from AIDS,[32] 1.1 million from tuberculosis, and 0.7 million from malaria.[33–38] By 2060, it is anticipated that ambient air pollution will result in 6 million to 9 million annual deaths in the absence of vigorous mitigation (Organisation for Economic Cooperation and Development, 2012; 2016). While 70% of air pollution-related deaths are due to non-communicable diseases, air pollution is a significant but underappreciated cause of non-communicable diseases. In 2015, air pollution was to blame for 19% of all cardiovascular deaths globally, 24% of deaths from ischemic heart disease, 21% of deaths from strokes, and 23% of deaths from lung cancer. In particular, cardio-respiratory conditions, harmful effects on human reproduction, low birth weight, cancer, and asthma flare-ups, notably among children, have all been linked to ambient air pollution.[39,40,2] Thus, Table 1 and 2 shows the results of air sampling and analysis. While Table 1 shows the concentration of particulate matter and selected heavy (petroliferous) metals, Table 2 shows the results of the level of air quality parameters. Cadmium is a known human carcinogen and was detected within the vicinity of the gas flare at the Ebocha Oil centre (0.008 µg/m^3) and at Chief Lucky's compound (0.005 µg/m^3) around Mgbede 7 oil well, located within 650m (measured on Google Earth Pro, Version 9.142.0.1) from the gas flare point. Although, concentration is within acceptable continuous lifetime exposure limits (WHO, 2000; 2006; 2018); it falls within known urban to industrial area concentration ranges which are from 0.005 micrograms per cubic meter (µg/m^3) up to 0.06 µg/m^3 respectively (WHO 1992); and above annual average acceptable exposure limits of 5 nano grams/m^3 (WHO, 2000; 2010).

Metals and particulate matter in air

Lead and nickel are also known human carcinogens. While lead occurred only at the flare site at a concentration (0.012 µg/m^3) marginal to the USEPA (NAASQ) guideline limits (0.015 µg/m^3); the concentrations of nickel, was in the range <0.002 to 0.014 µg/m^3 with highest concentrations occurring within 700m of the gas flare area (Table 1). The concentrations of nickel in ambient air were varied and largely influenced by industrial activities. Concentrations as high as 0.11-0.18 ug/m^3 have been reported in heavily industrialized areas (Bennet, 1994). It has also been stated that the main pathways of nickel exposure for humans are inhalation, ingestion, and dermal absorption. Assuming a daily respiratory rate of 20m^3, the amount of airborne nickel entering the respiratory tract will be within 0.1–0.8 µg/day with concentrations as low as 0.005–0.040 ug/m^3 in ambient air (WHO, 2000). This therefore means that people living within the Ebocha community may be exposed to up to 0.05 to 0.1 ug/m^3 of nickel daily which is a very dangerous level of exposure.

Table 1 Air particulate and heavy metals result

Points and results	Parameters (unit)					
	Cadmium (µg/m³)	Lead	Nickel	Zinc	PM 10	TSP
Gas Flare Point (Site A) 0m	0.008	0.012	0.014	0.011	20.6	72.3
Site B Ndoni Rd Pipeline; 650m updraft	<0.002	<0.009	0.012	0.014	22.6	72.4
Site C: Chief Lucky Ebocha; 650m downdraft	0.005	<0.009	0.01	0.011	22.2	70.4
Site D: Mgbede Uchenna Hotel; 2.5km downdraft	<0.002	<0.009	<0.002	<0.002	16.2	62.4
Site E: Living Guest House Aggah; 4.5km downdraft	<0.002	<0.009	<0.002	<0.002	16.3	56.4
Site F: Maxico House Okwuzi; 4.5km downdraft	<0.002	<0.009	<0.002	<0.002	18.2	52.6
STANDARDS	0.005 {Annual Average} (WHO,2000)	0.5 {Annual avg} 0.15 NAAQS (2021)	0.05 (OSHA)	5mg/m³ (OSHA)	20(Annual mean) WHO, 2018	120(Annual mean) WHO, 2005

**Boxes in RED show where limits are exceeded, while yellow indicates proximity to limits.*

Zinc concentrations were found in the range of <0.002 to 0.014 ug/m³ with maximum concentrations occurring around the gas flare site in Ebocha community. Although these concentrations are well within the acceptable daily exposure range (8 hours) of 5000 ug/m³; a study conducted in 2008 attempted to estimate the relationship between ambient air $PM_{2.5}$ zinc levels with hospital admissions and emergency department utilization by children in Baltimore, Maryland, USA. The study concluded that previous-day zinc concentrations (0.00863-0.02076 ug/m³) was associated with exacerbation in risks of paediatric asthma that are 1.23 (95% confidence interval, 1.07-1.41) times higher than those with previous-day low levels (<0.00863 ug/m³) of zinc concentrations after accounting for time-varying potential confounders.[41] This threshold is higher than the concentrations of zinc within the ambient air in the Ebocha gas flare area and therefore may be a predisposing factor to potential exacerbation in paediatric asthma. This, however, may need further investigations. Suspended particulate matter is characterized as; Total Suspended Particles, with diameters of <50-100 µm; PM_{10} (which are inhalable particles, have diameter of <10 µm and can enter the respiratory tracts through breathing and lodge deep inside the lungs) and thoracic particles, approximately equal to 10 µm. $PM_{2.5}$ or the fine fraction of suspended matter is <2.5 µm in diameter can penetrate the lung barrier and enter the blood stream.[42] This size was unfortunately not investigated in this study. Total suspended particles were within acceptable limits (120 ug/m³) in all locations while the PM_{10} component was above standards within the Ebocha area (20.6-22.6 ug/m³) and plotted marginally within the rest communities of Mgbede, Okwuzi and Aggah (Table 1). The MDC-Marlborough District Council (2021) has stated that health impacts including coughing and wheezing, asthma attacks, bronchitis, high blood pressure, heart attack, strokes and premature death can occur because of exposure to high concentrations of PM_{10}.

Table 2 Level of air quality parameters (Gases)

Points and results	Parameters (unit)					
	NOX (ppm)	SO_2	H_2S	O_3	CO	VOC
Site B Ndoni Rd Pipeline; 650m updraft	*0.058	0	0	0	8.41	0
Gas Flare Point (Site A) 0m	0.058	0.04	0	0	0	0
Site C: Chief Lucky Ebocha; 650m downdraft	0.039	0	0	0	2.88	0
Site D: Mgbede Uchenna Hotel; 2.5km downdraft	0.038	0	0	0	3	0
Site E: Living Guest House Aggah; 4.5km downdraft	0.057	0	0	0	0	0
Site F: Maxico House Okwuzi; 4.5km downdraft	0.053	0	0	0	0.87	0
STANDARDS	0.04	0.02	150 (WHO, 2000)	0.01	9 (WHO, 2010); 2 (India NAAQS, 1998)	0.75 (OSHA)

**Boxes in RED show where limits are exceeded, while yellow indicates proximity to limits*

Gaseous pollutants in air

The standard used for this analysis is the recent WHO, Ambient (outdoor) Air Pollution Guidelines released on the 2nd of May 2018 (unless, otherwise stated). NOx ranged between 0.038-0.058 ug/m³ in the study area and falls above standards (0.04 ug/m³) in almost all the sites (Table 2). Highest concentrations (0.058 ug/m³) where found around the flare area, although concentrations in other sites were still within this range. The lower concentration levels in sites 3 (Lucky) and 4 (Uchenna) may not be unconnected with the heavy rainfall that occurred shortly before sampling which may have aided washout of NOx gases from the air. Wet deposition and/or rainfall generally is known to 'scavenge' gaseous and particulate pollutants from the atmosphere.[43,44] Nitrogen oxides have both direct and indirect effects on human health ranging from upper respiratory problems, irritations and headaches, chronically reduced lung function and other indirect effects including damaging the ecosystem and roofing sheets through acid rain formation.[25] SO_2 was only detected within the gas flare site at Ebocha and at concentrations above acceptable limits (0.04 ug/m³). Exposure of the eyes to liquid sulphur dioxide, can cause severe burns, while repeated or prolonged exposure to moderate concentrations may lead to inflammation of the respiratory tract and lung damage. Foetal damage and impaired development have also been observed in experimental animals (Environmental Justice Australia Health, 2021). While H_2S and VOCs were below detectable limits at all sites, carbon monoxide were within acceptable standards in all locations based on the WHO (2010) standards. Only the Ndoni road site had appreciable

(8.41ug/m^3) concentrations which may be attributable to local traffic sources.

Air quality and health

Not just fatal diseases but also poor health and morbidity in millions of additional children are linked to air pollution. It makes breathing challenging. According to studies, it can cause eye irritation, bronchitis, asthma, and airway inflammation.[45,1,2,3,4,5] It may result in the production of mucus, coughing, and wheezing.[45,1,2,3] Children who breathe contaminated air are more likely to have potentially serious health issues, including acute respiratory infections like pneumonia.[39,40] Even if these illnesses do not result in death, they still have a negative impact on a person's development and general health. As the cellular layer lining the interior of the respiratory tract is more porous in young children, exposure can also have an impact on children's lung development. Low birthweight, intrauterine development retardation, and undersized for gestational age embryos are all associated with a mother's prolonged exposure to severe air pollution during pregnancy.[46–49,2] The growth and health of a child may potentially be negatively impacted in the long run by these issues. The effects of air pollution can exacerbate existing health problems.

Based on the World Health Organization, no country will meet air quality standards in 2021. Because low concentrations posed serious health risks. According to data compiled by IQAir, a Swiss pollution technology company, $PM_{2.5}$ levels in 93 cities were 10 times the recommended level. The current study, however, found high concentrations of cadmium and moderate concentrations of nickel and lead within 700m of the gas flare points. Cadmium concentrations occurred above maximum concentration limits in the gas flare point and at about 650m downwind around Mgbede 7; while lead and nickel occurred at very marginal levels bordering acceptable levels of maximum concentration. Cadmium, lead, and nickel are known human carcinogens.[45,1,2,3] High level exposure to cadmium oxide fumes in ambient air may lead to lethal levels of acute pneumonitis with pulmonary oedema. Long-term, high-level occupational exposure has been associated with lung changes, characterized primarily by chronic obstructive airway disease. There is also sufficient evidence that long-term occupational exposure to cadmium contributes to the development of lung cancer and may also cause cancers of the kidney and prostate. The International Agency for Research on Cancer (IARC) has classified cadmium and cadmium compounds as carcinogenic to humans (Group 1), meaning that there is sufficient evidence for their carcinogenicity in humans.[45]

The concentrations of nickel in ambient air quality was varied within 700m of the gas flare area combined with the WHO[50] cohort of a daily respiratory rate of 20 m^3 and an estimated continues exposure of the community to nickel levels up to 0.05 to 0.1 ug/m^3 daily can cause serious health challenges to the community. Nickel compounds are human carcinogens by inhalation exposure. Studies based on information of exposure and risk estimated in industrial populations gave an incremental risk of 3.8×10^{-4} for a concentration of nickel in air of 1 µg/m^3 assuming a linear dose– response. These concentrations correspond to an excess lifetime risk of 1:10 000, 1:100 000 and 1: 1 000 000 corresponding to 250, 25 and 2.5 ng/m^3, respectively. On this basis of this statistics, the WHO[51] concluded that no safe level for nickel compounds can be recommended.

The ASTDR has stated that exposure to nickel is mainly through breathing dust or fumes or by skin contact with nickel-containing metal. Moderate to long term exposures can lead to lighter symptoms like headaches, skin reactions, gastrointestinal upsets and more severe symptoms including epigenetic effects, nasal cancer, lung cancer, cardiovascular diseases, and respiratory diseases like lung fibrosis.[52] Also, the International Agency for Research on Cancer (IARC) has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans while the U.S Environmental Protection Agency has determined that nickel refinery dust and nickel subsulphide are human carcinogens. This places a high potential disease burden on communities and companies whose staff live and work within 1km radius of the gas flare site in Ebocha. This fact may be known to the Oil company operating here which made them to shift their residential operational base 1.6km upwind from the Ebocha Oil Centre where the flare stack is.

Zinc also occurred at a level where it could be a predisposing factor to potential exacerbations in paediatric asthma. This, however, may need further investigations. Although, we could not find any study relating paediatric asthma directly to exposures to gas flaring in the Niger Delta; Willis et al.[53] in a study in Pennsylvania concluded that community-level unconventional natural gas development exposure metrics were associated with increased odds of paediatric asthma-related hospitalization among young children and adolescents; while, Willis et al.[54] in another study claimed that the impacts of natural gas development on paediatric asthma are largely unknown but concluded further that there is evidence of associations between paediatric asthma hospitalizations in Texas and natural gas development, regardless of drilling type, thereby corroborating the findings of the earlier study and thereby supporting our disposition in this report.

PM_{10} component was found to be above standards within the Ebocha area while SO_2 was only detected within the gas flare area. It has earlier been stated that exposure of the eyes to liquid sulphur dioxide, can cause severe burns, while repeated or prolonged exposure to moderate concentrations may lead to inflammation of the respiratory tract and lung damage. Foetal damage and impaired development have also been observed in experimental animals (Environmental Justice Australia Health, 2021). This study also revealed widespread high concentrations of TSP. Although concentrations were at borders with maximum concentration limits. It has been found that long term exposure to even low levels of suspended particulate matter in the presence of SO_2 (as found within the Ebocha area) engenders serious health challenges. The WHO[45] reported that recent studies in Europe reveals that at low levels of exposure (with mean annual levels below 50 µg/m^3 and daily concentration levels usually not exceeding 125 µg/m^3) as is found in the study area; the effects on mortality (total, cardiovascular and respiratory) and on hospital emergency admissions for total respiratory causes and chronic obstructive pulmonary disease (COPD), have been consistently demonstrated.

These results have been shown, in some instances, to persist when black smoke and SPM levels were controlled for, while in others, no attempts have been made to separate the pollutant effects. In these studies, no obvious threshold levels for SO_2 have been identified. Short term health effects of exposure to combined SO_2, black smoke and particulates include increased mortality, morbidity, and deficits in pulmonary function. Some of the "lowest-observed effect" levels for short term exposure to particulate matter are excess mortality ~500 µg/m$_3$ (smoke); increased acute respiratory morbidity (adults) ~250 µg/m^3 (smoke); decrements in lung function (children) ~180 µg/m^3 (total suspended particulates)/110 µg/m^3 (thoracic particles). Other environmental effects include the soiling of exposed surfaces, impairment of visibility, potential modification of climate and contribution to acid deposition (EEA, 2020).

The study also revealed high level and widespread concentrations of NOx in the atmosphere of the study area with highest concentrations ($0.058ug/m^3$) occurring within the flare area. NOx known to impact mainly the respiratory system by causing inflammation of the air tract. Long term exposure as is common in the study area where continuous gas flaring has been ongoing for up to 60 years can decrease lung function, decrease respiratory functions, and increase the response to allergens. NOx also enhances the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects.[55] It is also associated with acid deposition which destroys forest and lake ecosystems, including leaf damage and reduced growth; destruction and corrosion of roofing sheets (common in the study area) and causes acidic rain which leads to the leaching of metals from soils into water bodies.[25,1,2,8] Thus, a brief description of the health effects caused by the different types of air-borne pollutants, though indicated while describing different pollutants, is again summarised in Table 3.[56–76]

Table 3 Effect of air-pollutants on human health

S/N	Pollutant	Characteristic if any	Source	Health effect
-1	-2	-3	-4	-5
1	Suspended Particular matter	Solid particular like dust, smoke and fumes; liquid particles like mist and fog.	Dust storms; cigarette smoke; smoke from burning of garbage fossil fuel; and fumes like those of zine or lend etc	Effects on breathing and respiratory of existing respiratory and cardiovascular diseases, alteration of body's defence systems against foreign materials damage to lung tissues, carcinogenic effects, and premature mortality still births). Elderly people and children are most sensitive.
2	Sulphur dioxide (SO_2)	Colourless gas; Taste threshold at about 0.3 ppm; and Odour threshold at about 0.5ppm	Combustion of oil, and coal in power stations or automobiles	Effect on breathing, respiratory illness, breakdown of lung defences, aggravation of existing respiratory and cardiovascular disease and death. Asthmatics and those suffering from chronic lung and cardiovascular diseases are sensitive to SO_2 exposures. Elderly people and children are greatly affected. It may lead to photochemical smog in some areas by oxidising the hydrocarbons.
3	Carbon monoxide gas (CO)	Colourless, tasteless, odourless gas at atmospheric concentrations.	Incomplete combustion of coal and oil (diesel, petrol etc) fuels.	The health threat of CO is maximum to those having cardiovascular disease, because it reduces oxygen delivery to organ and tissues. At elevated concentration, CO impairs visual perception, manual dexterity, and mental ability. Under short term exposure, it causes drowsiness and headaches. It also leads to formation of photochemical smog in some areas.
4	Nitrogen oxide (NO_x)	NO is a reddish-brown highly reactive gas. Odour threshold is at about 0.2ppm.	High temperature combustion in automobil4s (cars, etc) and some extent in thermal power stations	No plays a major role in tropospheric ozone formation. NO_2 irritates the lungs causes bronchitis and pneumonia, lowers resistance to respiratory infections. Asthmatics are most susceptibility and increases susceptibility to viral attacks. It also plays a major role in tropospheric ozone formation. Ozone reduces lung function, and is associated with coughing, sneezing, chest pain, and pulmonary congestion. It may affect all healthy people as well as the people with impaired respiratory system.
5	Lead	Colourless vapour. Consumed through inhalations. Lead compounds may also be consumed with food.	The major sources is leaded petrol used by cars. Ingestion and inhalation may also occur from food, water, soil or dust.	High lead exposures causes seizures, mental behavioural disorders. Foetuses, infants and children are especially to low doses, resulting in disorders of central nervous system. Lead uptakes may be a factor in high blood pressure and heart diseases.
6	Ozone (O_3)	Colourless gas. Threshold odour is about 0.3 ppm.	A secondary pollutant produced by photochemical pollution, being the largest constituent of photochemical smog along with PAN, etc.	Ozone reduces lung function, and is associated with coughing, sneezing, chest pain, and pulmonary congestion. It may affect all healthy people as well as the people with impaired respiratory system.
7	Carbon dioxide gas (CO_2)	Colourless gas found in air.	Combustion of coal, petrol and diesel.	Increasing concentrations over the years cause green house effect, leading and climate changes.
8	Nuclear waste	Invisible radioactive emissions and gases	Nuclear power plants, nuclear weapon testing, wars, etc.	Causes, radioactivity contamination of areas; cancers mutations, deaths.

Adapted from Garg and Ranjini (2008)

Conclusion

The government's and oil multinationals' zero-sum methodology has only adversely affected the Niger Delta environment's air pollution. This, combined with the activities of local actors who vandalize oil pipelines and engage in illegal oil bunkering, has amplified the Niger Delta's air quality problems. Thus, without persistent, concerted, and participatory measures to defend local people's rights and safeguard their environment, the region's chronic air quality will further worsen. In line with the aim and objectives of this study, air quality was investigated in communities in the Mgbede Oil Fields of South-south Nigeria. The study attempted to determine air quality effects of

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gas flaring in the area using standard methods (ASTM D1914) and compared air quality in the study area with international standards for ambient air quality. From the analysis of air samples, the study concluded that the concentrations of cadmium, lead and nickel which are known human carcinogen, and most other pollutants like SO_2 occurred in higher concentrations within 700m of the gas flare area and this potentially places a high potential disease burden on the community and companies whose staff live and work within 1km radius of the gas flare site in Ebocha. This may also be the reason why the Nigerian Agip oil company relocated its field residential base from within the flare area in the Oil Centre to a location (New Base) about 1.6km upwind from the gas flare point.

Zinc also occurred at a level where it could be a predisposing factor to potential exacerbation in pediatric asthma. This, however, may need further investigations while, PM_{10} component of air was found to be above standards within the Ebocha area while SO_2 was only detected within the gas flare area. This study also revealed widespread high concentrations of TSP. Although concentrations were at borders with maximum concentration limits. The levels of suspended particulate matter in the presence of SO_2 (as found within the Ebocha area) may engender serious health challenges including high effects on mortality (total, cardiovascular and respiratory) and on hospital emergency admissions for total respiratory causes and chronic obstructive pulmonary disease (COPD). The study also revealed high level and widespread above standard concentrations of NOx in the atmosphere of the study area, with highest concentrations ($0.058ug/m^3$) occurring within the flare area. NOx is known to impact the respiratory system, destroy forest and lake ecosystems, cause corrosion of roofing sheets (common in the study area) and leads to acidic rain which leaches metals ions from soils into water bodies. It can be safely concluded therefore that the quality of air in the area is not only influenced by continuous gas flaring and other oil production activities like drilling waste and oil spills in the area but occur at levels above acceptable international standards where environmental health could be adversely affected.

Recommendations

In the light of the foregoing, this study recommends the following.

i. Relocation of all living homesteads with adequate compensation away from 1km radius of the flare area.

ii. The federal government/oil companies should acquire all (with adequate compensation) all landed property within 1km radius of the flare stack.

iii. The ministry of environment and environmental regulatory bodies should make sure that the EMP (environmental mangaemet plan) should be strictly adhered to and done regularly.

iv. A comprehensive health assessment of the inhabitants of the communities in the Mgbede Oil Fields.

v. Further study to determine the relationship between gas flaring and pediatric asthma in the study area.

vi. The federal and state government to improve healthcare delivery in the study area and establish a special health insurance scheme/ trust fund for inhabitants to cushion the effects of long-term exposure to pollutants from oil producing activities.

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