POLICY BRIEF

REVISED Ambient Air Pollution and Chronic kidney disease risk in Deltan communities: A Policy Brief, 2023

[version 3; peer review: 1 approved, 2 approved with reservations, 1 not approved]

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Abstract

Chronic kidney disease (CKD) is a persistent, devastating, yet neglected, non-communicable disease, particularly in developing and emerging countries. The traditional risk factors for CKD, such as hypertension and diabetes have received relatively ample attention but do not sufficiently explain the high burden of CKD. Ambient air pollution is an emerging environmental risk factor for CKD; however, epidemiological data and evidence are lacking for susceptible populations in developing countries.

The Niger Delta region of Nigeria is a petrochemical hub known for environmental degradation, including air pollution, and thus, serves as a good case study for investigating the association between air pollution and CKD. This brief is based on an exploratory mixed-methods study conducted in four communities situated near an oil and gas refinery in Warri, Nigeria, to explore perceived and actual air pollution risks and determine whether long-term exposure to ambient air pollution is associated with CKD.

Air pollutant concentrations measured in partnership with citizen scientists using portable air sensors, showed that all except one air pollutant (ozone) exceeded the WHO acceptable limits in all four communities. PM2.5 ranged from 22.8 to 28.0 μg/m^3, PM10, 40.6 to 55.5 μg/m^3, and CO2, 584-652 ppm. The overall prevalence of CKD was 12.3% but even higher (18%) in a socially deprived semi-urban community closest to the oil refinery. Hypertension, diabetes, other behavioral risk factors, and exposures associated with CKD were prevalent in the four communities and environmental health

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information was lacking.

A multifaceted approach is required to mitigate air pollution and the associated NCD risks in the region. The government needs to invest in air monitoring services, cleaner technologies, and environmental risk communication through various media channels. We strongly recommend public inclusion in planning, designing, and implementing educational interventions. Lastly, environmental risk factors such as air pollution should feature prominently in strategic plans for NCD prevention.

Keywords
air pollution, chronic kidney disease, petrochemical industry, particulate matter, environmental health

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REVISED **Amendments from Version 2**

This updated version maintains the same title and authors. The tables and figures also remain unchanged. We have slightly reduced the amount of empirical data to improve readability for the target audience. The section on High prevalence of CKD has been split into two sub-sections. The mean concentration of volatile organic compounds (VOC) have been included in the text.

Any further responses from the reviewers can be found at the end of the article

Introduction

Systematic reviews and meta-analyses have shown that air pollution increases the risk of kidney dysfunction by 4–70%, and persons residing or working near point sources of air pollution are at an increased risk (Okoye et al., 2022; Wu et al., 2020; Ye et al., 2021). However, these reviews were based on methodologically heterogeneous studies. In contrast, there is a proliferation of epidemiological and toxicological evidence of air pollution-associated respiratory and cardiovascular diseases. Evidence for air pollution associated with CKD is almost non-existent in Nigeria and Sub-Saharan Africa, and environmental epidemiological researchers from the Niger Delta region have stressed the general paucity of scientific evidence, advocating for research support to examine and assess the health risks associated with petroleum-related exposure (Ordinioha & Brisibe, 2013; Orisakwe, 2021).

Chronic kidney disease (CKD) is a persistent, devastating, yet neglected non-communicable disease (NCD) especially in developing and emerging countries (Vanholder et al., 2021). Chronic kidney disease is responsible for 3.4 million deaths worldwide and ranks 10th among the risk factors for global deaths and DALYs (Global Burden of Disease Collaboration, 2019). However, national, regional, and international agency communications and reports on non-communicable diseases intentionally or unintentionally do not feature CKD. Traditional risk factors for CKD, such as hypertension and diabetes, which receive relatively ample attention, do not sufficiently explain the high burden of CKD especially in the young population of the developing and emerging countries (Garcia-Garcia et al., 2015; Stanifer et al., 2016). Consequently, environmental exposures such as air pollution, are increasingly being recognized as significant risk factors for NCDs (World Health Organization, 2018).

Few reliable epidemiological studies on air pollution and kidney disease have been conducted among susceptible people living in the Niger Delta, Nigeria's greatest petroleum hub, with CKD prevalence exceeding 10% (Chukwuonye et al., 2018). The irreversible and progressive nature of CKD, the high prevalence and incidence rates, adverse outcomes, enormous costs of treatment, and the strain on individual and collective health costs should prompt all stakeholders to take action. The persistence of a combination of CKD and ambient air pollution (two top-ten risk factors for global deaths) despite existing environmental health regulations is concerning and deserves attention.

This document is based on an exploratory mixed-methods study with embedded citizen science inquiry, conducted in four communities situated near an oil and gas refinery in Warri, Nigeria, to explore perceived and actual air pollution risk and determine whether long-term exposure to AAP increases NCD risk. Details of the initial qualitative study (a focus group) have been published (Okoye et al., 2023), so we focus on findings from the quantitative study and citizen science inquiry. We provide epidemiological evidence of air pollution associated CKD in susceptible communities, the implications for policy, and recommendations for action. The Ethical Review Committee of the Hospital Management Board, Warri, Delta State, Nigeria (CHW/ECC VOL 1/226) and the School of Health and Social Care Research Integrity Committee, Edinburgh Napier University (2782647) approved the study.

Policy outcomes and implications

Despite the high burden of CKD in Nigeria, there is currently no national renal care policy, plan or programme. Although the updated National Health Policy published in 2016 (Federal Ministry of Health, 2016) explicitly states that all tiers of government and private sectors should commit to attaining health and good quality of life for all citizens, CKD was surprisingly not identified as one of the major NCDs requiring attention. This lack of recognition of CKD and the environmental risk factors important in the disease epidemiology, may explain why CKD and related NCDs are persistent.

The implication of this grave omission is far reaching. While resources are channeled towards the prevention and control of NCDs such as hypertension, cardiovascular disease, stroke and asthma, it is assumed that CKD, being a consequence of these NCDs, will be automatically addressed. So far, the evidence has shown the contrary, and this is possibly because CKD is a complex syndrome with multiple aetiologies beyond the 'usual suspects' and also a harbinger of hypertension.

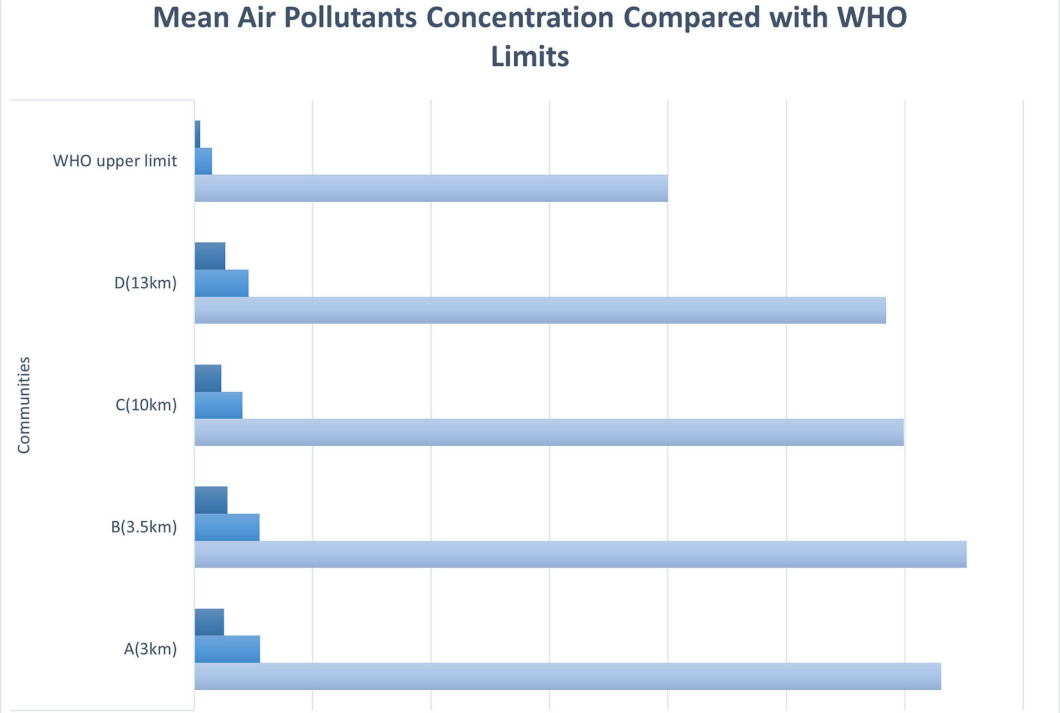
The long-term consequences of continually neglecting CKD in health policies include the persistence of hypertension and CKD with associated considerable morbidity and mortality; high health care expenditure which further impoverishes the affected members of society and their families.

The nephrology research community is well place to generate the needed evidence that may persuade policymakers to action. This brief therefore provides epidemiological evidence of high CKD burden in susceptible communities in the Niger Delta, Nigeria and the association with the greatest environment risk factor for diseases - air pollution.

Evidence of high ambient air pollutant levels in Warri

No air monitoring data existed in the State at the time this study was conducted. Ambient air pollutants were measured using portable air sensors, in collaboration with two environmental scientists and eight citizen scientists from four communities at varying distances from the petrochemical refinery: A (3 km/semi-urban), B (3.5 km/urban), C (10 km/urban), and D (13 km/rural). The air sensors were calibrated, and the citizen scientists were trained on how to use them and record their findings. For each community, two people took repeated measurements of six air pollutants over a period of 4 weeks. The geographical coordinates of each observer's location, temperature, and relative humidity were also recorded.

The average levels of $PM_{2.5}$, PM_{10}, and volatile organic compounds (VOCs) were higher than the WHO acceptable limits in all four communities. However, CO_2 levels were only acceptable in the communities that were the farthest away from the refinery (Figure 1). Ozone (O_3) was within the acceptable limits in all communities. The mean VOC ranged between 0.280 and 0.320 ppm (acceptable limit = 0.220 ppm). The mean PM_{10} concentration was highest in the two communities closest to the refinery (A = 55.54 and B = 55.43 $\mu g/m^3$), while $PM_{2.5}$ was highest in the urban community closest to the refinery (B = 28.01 $\mu g/m^3$) (Okoye, 2024, pp. 250-254). Higher than acceptable levels of NO_2 (>0.1-0.2 ppm) were recorded on certain days in all communities, whereas for most other days, it was negligible (0.0 or 0.1 ppm). The $PM_{2.5}$



	Communities				
	A(3km)	B(3.5km)	C(10km)	D(13km)	WHO upper limit
PM2.5 (µg/m3)	25.32	28.01	22.82	26.18	5
PM10 (µg/m3)	55.54	55.43	40.68	46.13	15
CO2 (ppm)	630.58	652.41	599.04	584.25	400

Figure 1. Mean air pollutant concentrations compared with acceptable limits.

concentrations for three of the communities are five times higher than the WHO acceptable limit and higher than IQAir (2023) report of 23.9 μg/m^3 and 14.8 μg/m^3 for Nigeria and Warri respectively, based on estimated satellite data (IQAir, 2023). Furthermore, the concentrations are much higher than 7.8 μg/m^3 achieved in Angola, the least polluted African country, which ranked 114th out of 134 countries, while Nigeria ranked the 35th most polluted.

The calculated individual exposure (IE = mean air pollutant concentration x duration of exposure) of all air pollutants was statistically significantly higher in participants who had CKD than those who did not. However, there was a weak negative correlation between estimated glomerular filtration rate (eGFR) and IEPM$_{2.5}$, IEPM$_{10}$, IECO$_2$, and IEVOC, respectively (Figure 2).

The HQ was estimated by dividing the mean concentration of the individual air pollutants by their respective WHO minimum acceptable limits. An HQ ≤1 is considered a negligible hazard, while >1 indicates exposure concentrations exceeding the reference limit, but not necessarily a statistical probability of harm occurring. The calculated HQ for PM $_{2.5}$, PM $_{10}$, VOC, and CO $_2$ based on the WHO minimum allowable limits, were elevated in all four communities. The total HQ for all pollutants were 11.27, 11.63, 9.63, and 10.63 for communities A-D. However, these aggregate figures do not necessarily represent magnitudes or synergies of health effects.

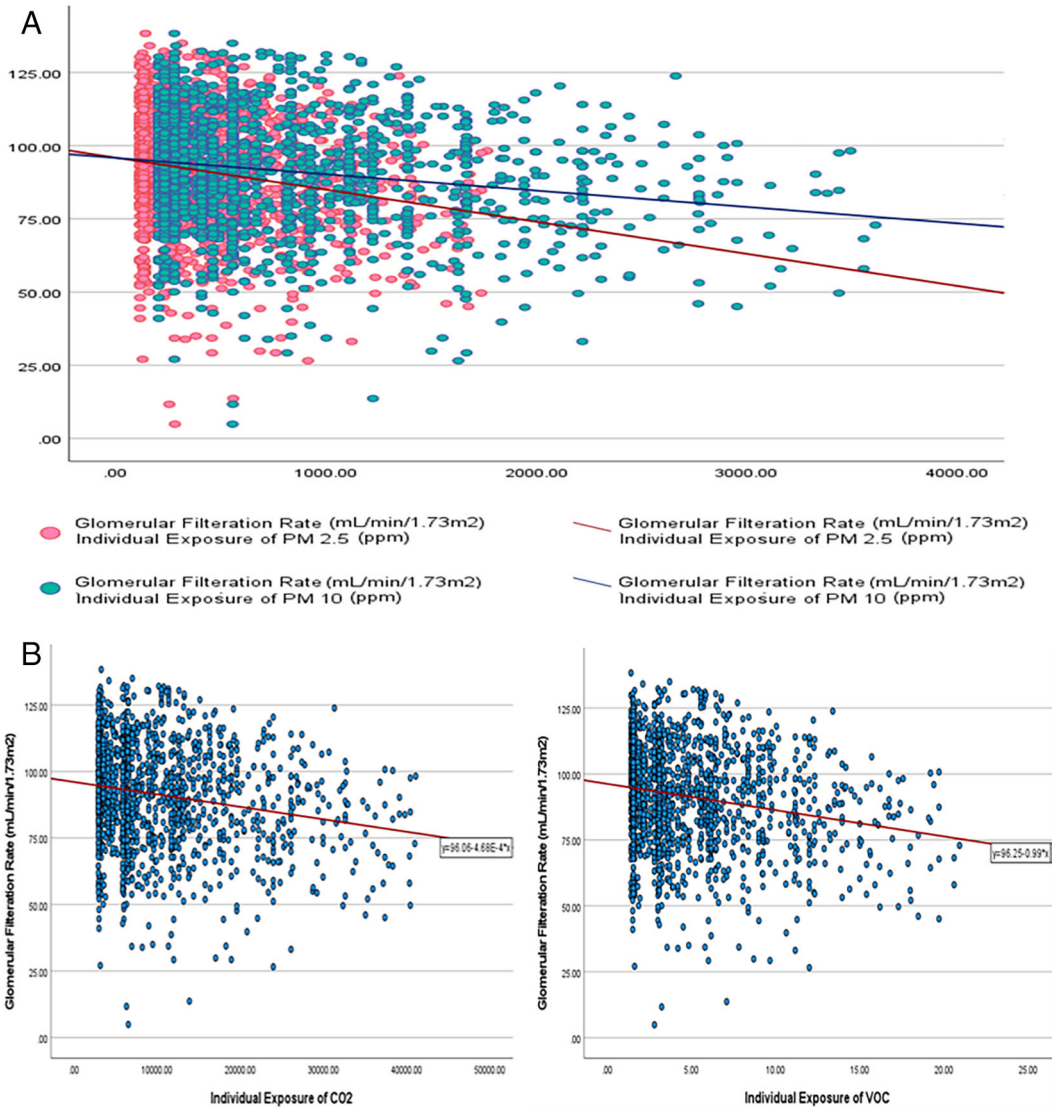


Figure 2. Correlation between calculated individual exposure (IE) to air pollutants and eGFR. A. Correlation between IE$_{PM2.5}$, IE$_{PM10}$ and eGFR. B. Correlation between IE$_{CO2}$ and eGFR; and IE$_{VOC}$ and eGFR.

High prevalence of CKD near the refinery

A cross-sectional study was conducted over a period of six months to assess the prevalence and risk factors of CKD among 1460 community members selected by multi-stage sampling from the four communities. Adults aged 18-64 years who had resided in their respective communities for at least 5 years were recruited. The four study communities are depicted as follows: 'A' - nearest to refinery/semiurban, B - near/urban, C - far/urban and D - farthest/rural, to ensure participants' privacy and anonymity. The majority of participants were female (71%) and there was no significant difference across the four communities. The mean age was 44±13 years; it was highest in far/urban and lowest in the nearest/semi-urban community ($P \leq .001$). More than half of participants in the far/urban (66.6%) and far/rural communities were above 50 years (56%), compared with 50% respectively for the near communities.

The overall prevalence of CKD, defined as dipstick proteinuria and/or an eGFR <60 ml/min was 12.3%. The prevalence was highest in the nearest/semi-urban community (17.9%) compared with 13.1%, 10.5%, and 8.0% in the near/urban, far/urban and farthest/rural communities respectively ($P \leq .001$). Proteinuria alone was detected in 6.8% of all participants, while 6.6% had a reduced eGFR of <60 ml/min. The prevalence of CKD reported across Nigeria and Sub-Saharan Africa varies greatly depending on the population studied, CKD definition and methodology; from as low as 2% to >20% (Abd ElHafeez et al., 2018; Chukwuonye et al., 2018). However, our findings demonstrate a higher CKD prevalence in the nearest/semiurban community, compared with a pooled prevalence of 10% and 13.7% reported for Africa and Nigeria, respectively (Abd ElHafeez et al., 2018; Raji et al., 2024).

Two-fifths of the participants with CKD were in stage 3A (i.e., eGFR 45-59 mls/min) which represents a mild to moderate decrease in kidney function requiring monitoring. The nearest/semi-urban and near/urban communities had a higher proportion of participants in stage 1 and 2 CKD (proteinuria with eGFR>60 ml/min) while the far/urban and farthest/rural communities had more participants in Stage 3A (Figure 3). Higher occurrence of proteinuria among participants closer to the refinery suggests a glomerular mechanism of kidney injury which has been previously reported (Blum et al., 2020; Li et al., 2021; Xu et al., 2016; Yan et al., 2014). However, further experimental studies are needed to establish this. In contrast, the lower prevalence of proteinuria among the farther two communities suggests that the mechanism of kidney damage may be different. Considering that the latter two communities had an older population, aging and related comorbidities may have contributed significantly to CKD.

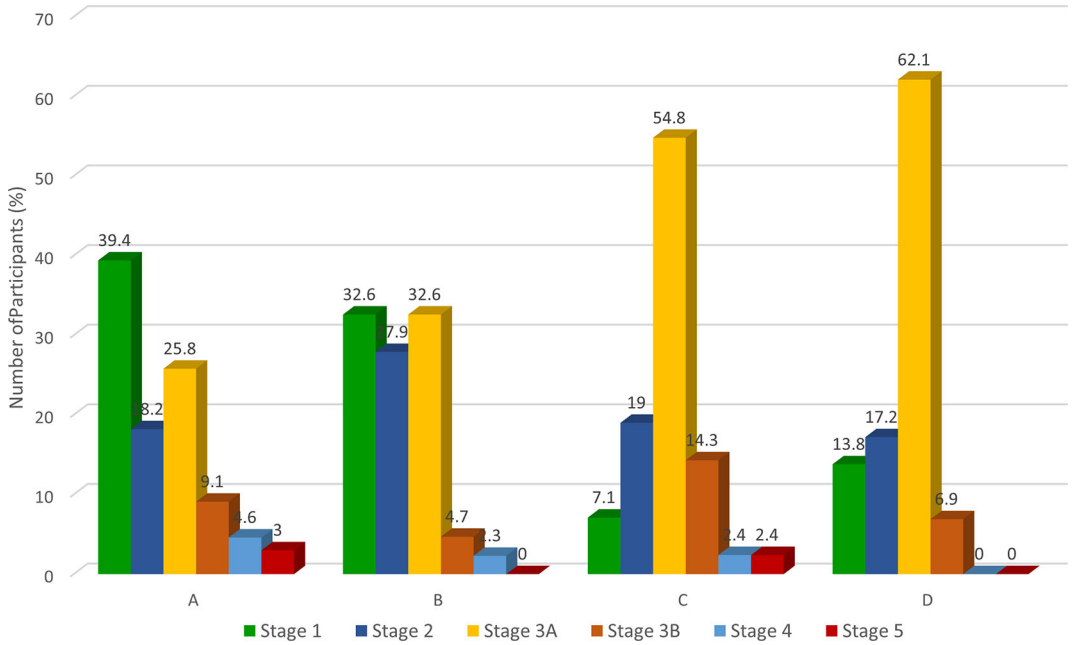


Figure 3. CKD staging across the four communities. *A=nearest/semi-urban| B=near/urban| C=far/urban| D=farthest/rural.

Air pollution-CKD Association

The risk factors significantly associated with CKD were proximity to the refinery, diabetes, hypertension, increasing age, low level of education, residence in urban/semi-urban areas compared to rural areas, use of hair dyes and spending more time outdoors. However, after adjusting for confounding factors such as gender, age, LOE, diabetes and hypertension, the statistically significant independent risk factors CKD were *proximity to the refinery* [OR=2.00 (1.43–2.81)], *increasing age* [OR=1.02(1.005–1.04)], *hypertension* [OR=1.61(1.12-2.31)], and *level of education* [OR=0.63(0.44-0.91)] (Okoye, 2024, pp. 275). In a further logistic mixed model using 'R', which accounted for clustering effects at household level, only *increasing age* was an independent risk factor for CKD [OR=1.26 (1.09-1.45), P=.002,]. This observation suggests that intrahousehold homogeneity significantly accounted for the variance observed. While proximity to the refinery did not sufficiently predict CKD risk, it probably acts synergistically with other prevalent risk factors and exposures to increase the risk for CKD as explained in the multicausation theory, which is applicable to most non-communicable diseases. On the other hand, adjusting for intrahousehold homogeneity led to reduced intra-group sample sizes which can cause non-observance of statistical effects even where it exists (Type II error).

There are emerging empirical evidence on air pollution-associated kidney disease, though a majority are based on studies conducted in the global north (Chan et al., 2018; Liu et al., 2020; Okoye et al., 2022; Wu et al., 2020; Ye et al., 2021). These studies consistently report that PM and NO_2 exposure increases the risk of CKD by 4-70%. Our findings strongly support that this impact of air-pollution on the kidneys also applies to disadvantaged areas, like the Niger Delta. There is a scarcity of similar studies from Nigeria and Africa as was reported in our systematic review of 14 studies, in which no study from Nigeria or Africa investigated CKD as an outcome (Okoye et al., 2022).

Lastly, the overall prevalence of hypertension, obesity, and diabetes was 33%, 28.5%, and 6.0%, respectively.

Social determinants of CKD risk

One-third (31.5%) of the population had less than secondary-level education, and 50.5% earned less than the minimum wage. Although 86% of the population was employed, 68% were self-employed, and only 3.8% were employed by the government. Of the 68% self-employed, the majority were petty traders. Several social risk factors and toxic environmental exposures associated with CKD and NCDs were prevalent among residents of the four communities. Behavioural factors included unhealthy dietary habits (70–90%), low physical activity (47.2%), and habitual exposure to potential nephrotoxins (37–44%). Four-fifths of the population was regularly exposed to petrochemical products as part of their daily lives, 72% used household chemicals regularly, 53.2% were regularly exposed to pesticides, and 49% were exposed to toxic chemicals or dust in their jobs. Other risk factors that were relatively less prevalent included hair dye use (19%), excess salt intake (15%), use of mothballs (14.4%), use of skin lighteners (12.7%), and current smoking (3.8%).

The concentration of multiple social and environmental risk factors in the studied population may explain the high prevalence of CKD and other NCDs. These findings support the multi-causation theory, drawing attention to the need for a multi-faceted approach to CKD prevention.

Low air pollution health risk literacy in Warri

Two-fifths of the 1460 survey participants perceived that their outdoor air was polluted, and the proportion was significantly higher (65%) among those residing near the refinery. Heightened perception of air pollution was significantly more common among young people, those who lived near refineries and urban areas, those who spent more time outdoors, and those who cooked with propane gas. Refinery activities were cited as the most popular source of air pollution. A higher proportion of those residing near the refinery attributed air pollution to the refinery/gas plant: 40.6% and 18.0% for communities A and B, respectively, compared to 7.2% and 6.1% for the farther communities C and D, respectively. Other perceived sources of air pollution include poor environmental sanitation, traffic emissions, generator fumes, open waste burning, and illegal oil refining (Figure 4).

Most participants (70.1%) perceived that air pollution is associated with health risks, 13.4% responded negatively, and 16.4% did not know. The majority of study participants (60.1%) were unaware of any medical conditions associated with air pollution (Figure 5). This low literacy level suggests that the necessary preventive measures, such as individual behavioural changes, are lacking, and this may contribute to the high burden of air pollution associated NCDs in the community.

Only 12.3% of the participants agreed that the ambient air environment was well controlled and up to 60% placed responsibility solely on the government. Among those who agreed that they had a role to play, the responses included maintaining environmental sanitation (53%), complaining to the government and advocacy (32%), and using personal protective measures (3.7%).

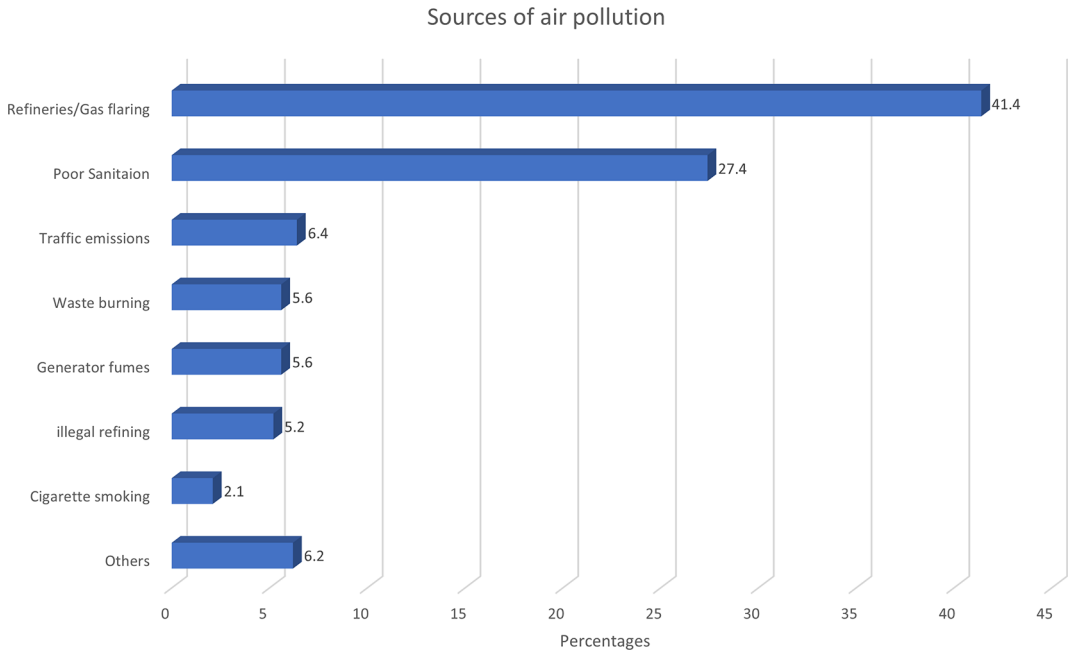


Figure 4. Participants' perception of sources of air pollution (N=628). Others = Bakery, other industries, dust, overcrowding, sawmills, septic pits, swamps.

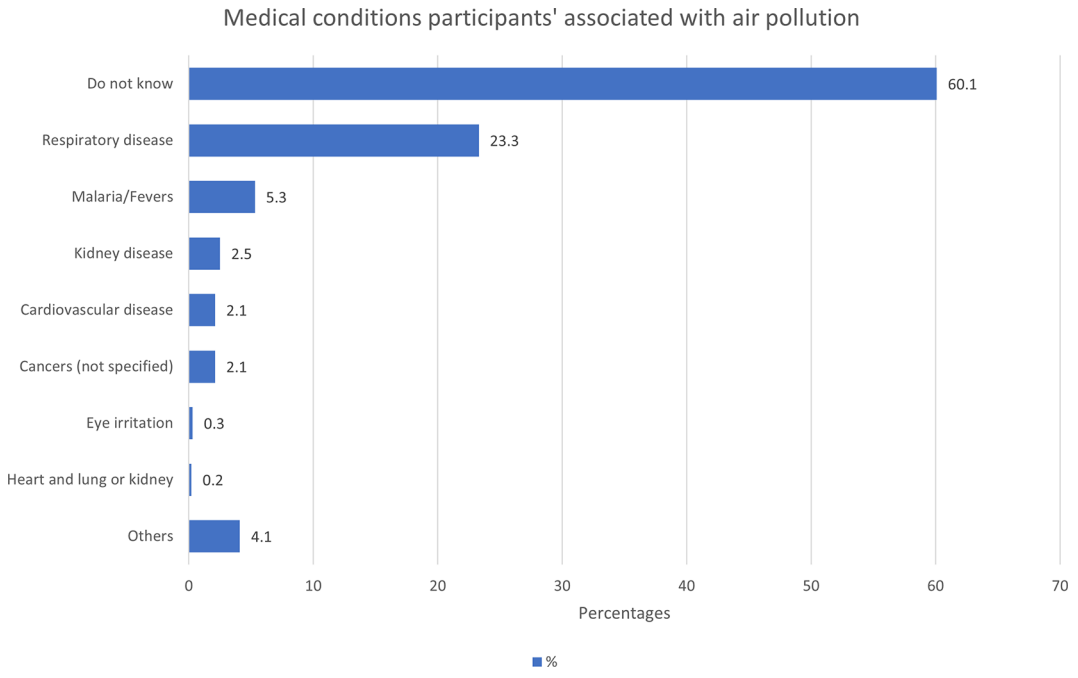


Figure 5. Medical conditions the participants associated with air pollution (N=1460). Respiratory disease = cough, catarrh, difficulty with breathing, chest pain, asthma, COPD, lung cancer, lung disease | Others= infections (not specified), measles, small pox, air borne disease, diarrhoea, nausea, liver disease, stomach ache, heart burn.

Implications for policy

- There is currently no renal care policy in Nigeria or Delta State, and the most recent National Health Policy does not capture CKD among NCDs. This critical omission needs to be urgently addressed, as the enormous burden of CKD is not debatable. Furthermore, CKD is often the secondary cause of mortality in patients with both NCDs and chronic infections.

- Nigeria lacks continuous air monitoring data and has met only one out of the nine Clean Air Targets (United Nations Environment Programme, 2021). Although the ministry of environment is saddled with the responsibility of monitoring and maintaining air quality, the infrastructure and equipment are lacking. However, some private organisations provide air monitoring services at a cost but more importantly, we have demonstrated that affordable portable devices are reliable and can be easily deployed to achieve the same purpose.

- In the broadest policy terms, increasing efforts towards environmental risk protection, including air monitoring, environmental risk communication, reducing poverty, and investing in public health services would improve population health and reduce inequalities, especially for susceptible persons. We have presented evidence of low environmental health literacy, low socio-economic status, and poor health indices among the communities studied, which should stimulate all stakeholders to action.

- Poverty and ignorance of health-promoting information increase the burden of CKD through mechanisms related to health care accessibility, unhealthy behaviours, biological factors (e.g., low birth weight, inadequate nutrition), and environmental factors (e.g., exposure to pollutants, communicable diseases, lack of clean water, and sanitation) (Luyckx et al., 2017; Stanifer et al., 2016). Therefore, multisector integration, interdisciplinarity, and public inclusion in shaping policies and planning health interventions are needed to ensure effectiveness and reduce inequalities.

- Our findings reveal that communities in Warri are simultaneously exposed to household, community, and global environmental risks - a Triple Risk Overlap (Smith & Ezzati, 2005). The high prevalence of CKD risk factors and low awareness of CKD and NCD status among the study participants suggests low health literacy and poor health-seeking behaviour, which necessitates more persuasive and inclusive public health educational interventions. Second, out-of-pocket payments are an additional hindrance to positive health-seeking behaviours and need to be addressed urgently.

Lastly, our findings are generalisable to similar vulnerable populations across the globe who reside near point emission sources. Therefore, the following recommendations may be useful for future public health interventions in these settings.

Actionable recommendations

Table 1 below details recommendations based on our findings.

Table 1. Actionable recommendations, responsible stakeholders, and feasibility.

Recommendations	Responsible stakeholders	Feasibility
SHORT-TERM		
• Equip all primary health centers (public and private) to screen high-risk persons for CKD- blood pressure monitors, urinalysis dipsticks, and portable point-of-care serum creatinine or cystatin C analyzers.	All tiers of Govt., Non-profit organisations, Philanthropists.	PHCs already exist across the country but need upgrading.
• Public environmental health education in collaboration with all stakeholders.	Govt. agencies, public health professionals, educators, environmental scientists, sociologists, industries, non-profit organizations, and community leaders/members.	There are existing govt. public health awareness structures but need to be more inclusive from planning to intervention.
• Train the trainers who will sustain the campaign for clean air at the community level.	Govt. agencies, public health professionals, educators, environmental scientists and sociologists.	The human resources required are available but government collaboration and support is need.
• Preserved forests and maintain green spaces around residential areas.	Govt. agencies, Policy makers, environmental scientists, community members.	The Delta State Ministry of Environment has initiated a number of tree-planting campaigns, which are commendable and can be replicated across the country.

Table 1. *Continued*

Recommendations	Responsible stakeholders	Feasibility
• Consider re-introducing the Delta State haemodialysis subsidy to address the suffering of people already living with kidney failure.	State Govt, Policy Makers.	Haemodialysis subsidy has been tried in Delta State (2013-2016) with excellent patient outcomes. Re-introduction should be strategic and transparent; a cost-benefit analysis will be required.
• Enforce stringent air pollution standards, regulations, and legislation. Environmental impact assessments should be conducted in accordance with ethical standards.	All tiers of Govt., regulatory bodies, and urban planners.	The standards, regulations and legislation already exist but should be enforced.
MEDIUM TERM		
• Invest in air monitoring services and data; cleaner technologies (e.g., electric transportation, solar, and wind power).	Federal and State Govt, relevant agencies (health, energy, technology), industries, environmental scientists.	Collaborate with existing private establishments and community volunteers to achieve air monitoring.
• Ensure transparent environmental risk assessment and communication.	Federal and State Govt, relevant agencies (health, energy, technology), industries, environmental scientists, educators and public health professionals.	Plan and execute risk communication strategies in collaboration with all stakeholders. Disseminate and sustain efforts through various media channels and community *Champions.*
• Persuade the public to adopt healthy behaviors and routine annual health screenings through stricter policies e.g. demand a medical certificate of fitness before driving license or international passport renewals.	Federal Govt., Policy makers.	Annual medical certificate can be obtained from accredited public and private health institutions but endorsed by only registered high-cadre health professionals.
• Support the research community through grants to generate robust evidence that will inform effective health and social interventions.	All tiers of Govt., non-profit organisations, industries, philanthropists.	The National Health Policy recognises the importance of "strengthening the evidence". The federal govt. efforts through the Tertiary Education Trust Fund (TETFUND) is commendable but more opportunities should be created.
LONG TERM		
• A National Renal Care Policy is needed.	Federal Govt, relevant govt. agencies, policymakers, Nigerian Association of Nephrology.	The renal care policy recommendations (unpublished) proposed by the Nigerian Association of Nephrology should be adopted and integrated with the existing National Health Care Policy.
• Kidney health prevention and treatment should be covered by National and State health insurance schemes	Federal and State Govt.	The health insurance schemes already exist but need to accommodate more kidney related expenditure.
• Environmental risk factors such as air pollution should feature prominently in strategic plans for NCD prevention.	Federal Govt agencies (MOH, MOE).	The current National Health Policy does not explicitly highlight the role of mitigating environmental exposures in achieving sustainable health.
• Socially empowering policies to improve the indices of susceptible populations that have suffered long-term environmental exposure.	Federal and State Govt. and Legislators	Skill acquisition training and empowerment has been successfully implemented for certain vulnerable groups in Nigeria and can be replicated in oil and gas-situated communities.

Limitations of the study

Air monitoring conducted for a period of 4 weeks served as a surrogate for annual exposure; this was due to the high financial implications and tenure of the research. Urine protein was tested using dipsticks rather than the than the albumin-creatinine ratio, which is more reliable due to the high cost of the test. However, the dipsticks test is highly specific though less sensitive in detecting low levels of proteinuria. Lastly, the diagnosis of CKD was based on a spot-assessment of urine protein excretion and eGFR and may have led to an over- or underdiagnosis of CKD. The participants' who had abnormalities were unwilling to repeat their tests due to the fear of confirming a new disease, despite repeated attempts at inviting them through phone calls and physical visits to the community. Although this was a large sample study, the cluster size variability led to significant design effects in the prediction model.

Despite the limitations, the strength of the underlying study lies in the innovative combination of multiple research methods, interdisciplinarity and involving citizen scientists in addressing a public health problem. The extensive consideration of potential clinical, social and environmental NCD risk factors and adjusting for confounding factors strengthens the study quality.

More research is required from underserved areas to explore: this exposure-effect relationship, the mechanism of air pollution associated CKD and potential interventions to reverse it, and to develop educational interventions that would effectively improve public awareness of environmental health risks. Based on our experience with intrahousehold sample selection and the resultant design effects, we suggest that subsequent studies should consider systematic selection of households (the more, the better) and intra-household selection to ensure a constant cluster size and acceptable design effects.

Conclusion

The main purpose of this briefing is to draw attention to the seriousness of chronic kidney disease, the possible contributory role of environmental exposures such as air pollution, and to provide information that may support decision makers in developing and implementing policies and strategies to address the problem.

Our findings show that the communities are exposed to unacceptable levels of air pollution, with a high prevalence of CKD, hypertension and other risk factors for CKD. We report that long-term exposure to ambient air pollution is associated with chronic kidney disease, which is consistent with previously published evidence. In addition, we presented evidence of the low socioeconomic indices, poor health literacy, and indirect health impacts of air pollution.

Addressing air pollution-associated CKD requires a multifaceted approach involving policymakers, health care professionals, the academic community, industries, and the general public. By incorporating air pollution-associated health risks into policymaking, clinical practice, health professionals and public education, it is possible to reduce the burden of CKD and other NCDs and improve public health outcomes.

Disparities in access to clean air and environmental health information are environmental injustice with significant threats to sustainable health and therefore require the urgent attention of policymakers. The co-benefits of effective air pollution mitigation surpass environmental sustainability to include improvements in health, social well-being, and reduction in health inequalities.

Data availability statement

Edinburgh Napier University: Ambient Air Pollution near Petrochemical Industries and Chronic Kidney Disease Risk: Integrating Citizen Science within an Exploratory Mixed Methods Study (dataset) https://doi.org/10.17869/enu.2024.3559366.

This project contains the following underlying data:

- AIR MONITORING DATA.xlsx
- Codebook - air pollution - 17-03-2022.docx
- GFR.xlsx

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- School of Health and Social Care, Edinburgh Napier University.
- Leaders and members of the study community.
- Research Assistants and volunteer health care professionals: Dr. Ejiro Orhewere, Dr. Oritseweyinmi Edema, Dr. Toritseju Ereku, Miss Chigozie Offiah, Miss Osarumen Uwadiae, and Mr. Clement Ugbunu.
- Community volunteers (citizen scientists)
- Dr Mininim Oseji, Permanent Secretary, Ministry of Environment, Delta State.

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Open Peer Review

Current Peer Review Status: ? ✓ ✗ ?

Version 3

Reviewer Report 16 January 2025

https://doi.org/10.5256/f1000research.176702.r358176

✓ **Nikola M Pavlović**
University of Niš, Niš, Serbia

The authors have followed my instructions and comments, and I believe the article is now suitable for indexing. I have no further requests for revisions.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 2

Reviewer Report 30 December 2024

https://doi.org/10.5256/f1000research.172808.r348567

? **Karl Kilbo Edlund**
[1] Occupational and Environmental Medicine, School of Public Health and Community Medicine, Institute of Medicine, Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden
[2] Occupational and Environmental Medicine, School of Public Health and Community Medicine, Institute of Medicine, Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

Okoye and colleagues have conducted a much-needed study of air pollution and CKD risk in communities residing near a petrochemical plant in the Niger river delta in Nigeria. They present

timely policy advice that combines previous evidence and their own findings of air pollution levels, population health, population health literacy, and the relationship, in their data, between air pollution exposure and prevalent CKD. The authors highlight the need for expanded care options for Nigerans with CKD as well as the urgent need of reduction of PM emissions from the petrochemical industry. The text is mostly well-written and the recommendations mostly rest on a solid scientific literature. I believe their implementation would benefit Nigerians much along the lines described by the authors.

In this review, my main concerns relate to 1) the inclusion of considerable previously unpublished empirical data and analyses in this policy brief, which in this genre should rather be kept at a minimum, 2) the formulation of some of the actionable policy recommendation require further work. At the end of the review, I also include some minor comments for the authors' consideration.

Starting with the first concern, regarding the inclusion of primary data and analyses in this policy brief. As highlighted by the authors, there is considerable previous evidence of adverse effects on kidney health associated with air pollution, and even some evidence specifically for petrochemical industry. This means that, in the context of this policy brief (notably unlike if this were an original article or a dissertation) the empirical, quantitative evidence put forth here do not serve the purpose of testing the hypothesis that there are adverse effects on kidney health of air pollution, but rather to emphasise that the adverse health effects seen elsewhere are highly likely to extend to the Niger river delta as well. In the first scenario, the data provided here, although filling an important gap in previously available data and describing the high prevalence of undiagnosed CKD in this population, do not provide particularly strong evidence for adverse kidney effects of PM from the petrochemical industry, above and beyond what is already available. Key limitations that need to be kept in mind are that these data are cross-sectional, that participant selection and sampling procedures are not described, that PM measurements were taken only during certain times and through a less standardised process and that no validation is described etc. (These limitations are of course fully understandable given the challenges of data collection.) On the other hand, these data are strong when instead considered as a validation that the likely large impact of PM on kidney health noted in previous literature also applies to this area.

With this in mind, I would suggest the authors restructure the section ("High prevalence of CKD and risk factors") where the association between air pollution and CKD is presented. Firstly, it would help the reader if this rather long section were subdivided, as it currently presents the two rather different topics of CKD prevalence and then the PM-CKD association. Secondly, I believe that it would lend more strength to the authors' recommendations, if the authors would present a little more extensively the rapidly growing literature supporting an air pollution-CKD association, with particular note to any previous studies in similar settings. Thirdly, I think the authors should reconsider the currently rather technical discussion on regression analyses and statistical methodologies, given that this is presumably of little use to a policy-maker who is not themselves trained in quantitative analysis; possibly, it suffice to say that the prevalence of CKD was higher closer to the refineries adjusting for age, sex, BMI, if this is in line with how the authors interpret their results.

Turning to the second concern, relating to the policy recommendations. The conclusions bullet-pointed under "Implications for policy" are substantive, well-written, and supported by literature and empirical findings. However, I have concerns with multiple recommendations provided as

actionable recommendations in table 1. In the following, I will for practical reasons refer to them as numbers, with recommendation 1 as the first recommendation in the table.

- For recommendation 1, the call for CKD screening is a charitable one. However, the decision on initiating screening is a difficult one, and should include a cost-benefit analysis as well as strategies to accurately identify individuals with false-positive screening results. Furthermore, this analysis needs to account for the availability of treatment options.
- Similarly, the subsidy reintroduction mentioned in recommendation 5 would need some cost-benefit analysis, or if such is available elsewhere, as a reference.
- The suggestion of a medical fitness certificate before international passport renewals in recommendation 9 might not be compatible with the UN's Universal Human Rights (article 13, section 2). However, this is beyond my area of expertise.
- The National Renal Care Policy referred to in recommendation 11 is not mentioned or detailed in the policy brief, and for the non-Nigerian it might be difficult to know what the authors refer to here.
- Including environmental risk factors in NCD prevention plans, as suggested in recommendation 13, could be supported by an attributable fraction calculation, illustrating the magnitude of these risk factors in comparison to other relevant, traditional risk factors.

Minor comments:

- The air pollutant levels, measured during 4 weeks, are compared to the annual WHO limits. While this is presumably necessary due to lack of more extensive data, it would be recommended to mention this.
- Hazard quotients (HQ) are presented for $PM_{2.5}$, PM_{10}, VOC and CO_2, no concentration or WHO limit is presented for VOC. Furthermore, CO_2, while central to global warming, is not a criteria pollutant and there is little literature to support adverse health effect of direct CO_2 exposure. It also seems, purely from the figures themselves, that HQs for the pollutants have been summarised to a combined HQ, and it is questionable whether this method can capture magnitudes of and synergies between health effects in any meaningful way.
- The in-text link is missing for a key reference in the Introduction (Chukwuonye et al., 2018). Furthermore, the "Publisher Full Text" link in the first author's thesis redirects not to the thesis but to a conference abstract.
- The authors report using "R studios" for statistical analyses, yet it should be noted that the RStudio software is merely a front-end for R, which is the statistical programme used. If the authors wish to state their choice of statistical software in this policy brief (see the first major concern outlined above), I would recommend stating it more correctly as R.

Does the paper provide a comprehensive overview of the policy and the context of its implementation in a way which is accessible to a general reader?

Partly

Is the discussion on the implications clearly and accurately presented and does it cite the current literature?

Partly

Are the recommendations made clear, balanced, and justified on the basis of the presented arguments?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Environmental epidemiology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 30 Dec 2024

Ogochukwu Okoye

We appreciate your review and useful critique.
We acknowledge your main concerns and wish to respond here. However, we will revise our manuscript where needed.

1) Regarding the inclusion of considerable empirical data and analysis: The original manuscript submitted had minimal empirical data as expected for a policy brief. However, we included more data in response to two of the previous reviewers. We agree that the intended audience may find some aspects of the manuscript too technical and we will make some adjustments to minimise the data and complexity.

Although the empirical data has not been published in any journal, we included a link to the Thesis underlying this study. We agree that our data serves to support the existing literature on PM and kidney disease, although these studies are mostly from the global north. While we note the study limitations, we agree that our findings are a strong validation that air pollution associated health effects noted elsewhere also applies to the Niger Delta.

2) The section on "High prevalence of CKD and risk factors" will be split to improve clarity.
3) Response to concerns about some 'actionable recommendations:
a)We agree that whole population screening may be cost-intensive and require cost-benefit analysis. However, screening of high-risk populations is currently recommended in Nigeria and globally. (KDIGO).
Treatment options for early CKD mostly entails addressing identified risks to slow progression of the disease. These treatment measures are widely available.

b)We agree that the subsidy re-introduction would need a cost-benefit-analysis, which we consider a great suggestion for further studies.
c) Thank you for drawing our attention to the possible Human Rights implication of requiring a medical fitness certificate before issuing international passport. We will explore the feasibility and revise this accordingly.

d) Regarding the calculated Hazard Quotients and Total HQ, we stated that the figures do not necessarily represent a statistical probability of harm occurring. However, we have included a further statement that 'the Total HQs do not represent synergies or magnitude of health effect'.

e) The concentration for VOC was not included in Figure 1, for simplicity of presentation as the values were less than 1. However, the HQs for VOC were included in the calculation of total HQ. Again, for simplicity, we have not included these details in the text. All information is available in the underlying Thesis.

f) The two references highlighted will be sorted. Thank you.
g) We will replace 'R studios' with 'R'. Thank you

Competing Interests: No competing interests were disclosed.

Version 1

Reviewer Report 14 September 2024

https://doi.org/10.5256/f1000research.159925.r279715

Nicholas Osborne
[1] The University of Queensland, Saint Lucia, Queensland, Australia
[2] The University of Queensland, Saint Lucia, Queensland, Australia
[3] The University of Queensland, Saint Lucia, Queensland, Australia

Overall comments
This study proposes to discover association between air pollution and CKD. Unfortunately an accurate measure of air pollution was not available. Similarly an accurate measure of the health outcome, kidney function was not available. Diagnosis of CKD requires two measures of kidney function (usually by eGRF) at least 3 months apart. Consequently attempts to examine the relationship do not have data of sufficient quality to make the linkage.
The paper was not conducted as a policy brief. Large amounts of extant literature were missing from the evidence base presented.
The paper has a limited data reference list.

Specific comments
Abstract mentions CKDu in passing without mentioning its prevalence in certain LMIC settings. The disease CKDu in Sri Lankan and Mesoamerican settings.

Does the paper provide a comprehensive overview of the policy and the context of its implementation in a way which is accessible to a general reader?
No

Is the discussion on the implications clearly and accurately presented and does it cite the

current literature?
No

Are the recommendations made clear, balanced, and justified on the basis of the presented arguments?
No

Competing Interests: Dr Nicholas Osborne received an honorarium for speakers' fees from Reckitt, an honorarium from Taylor and Francis Publishing, and payment for assisting the Federal Court of Australia.

Reviewer Expertise: Environmental epidemiology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 30 Sep 2024

Ogochukwu Okoye

We are grateful for your detailed and constructive critique which has helped to significantly improve the merit and quality of our manuscript.

Comment: This study proposes to discover association between air pollution and CKD. Unfortunately, an accurate measure of air pollution was not available.
Consequently, attempts to examine the relationship do not have data of sufficient quality to make the linkage.
Response: Extensive methodological and statistical details were deliberately omitted as this document was targeted at policymakers. However, we have provided additional information in the text to describe how air pollution was measured and other details are available in the link to the underlying study. Page 4

Comment: Similarly, an accurate measure of the health outcome, kidney function was not available.
Diagnosis of CKD requires two measures of kidney function (usually by eGRF) at least 3 months apart.
Response: We agree with your observation. The authors initially set out to obtain at least two measurements from participants who have abnormalities but encountered challenges with participant retention. This limitation has been highlighted in more detail.
However, all biological samples were handled and processed by a reputable independent laboratory with documented standard operating procedures to ensure accuracy and reliability. Page 11

Comment: The paper was not conducted as a policy brief. Large amounts of extant literature were missing from the evidence base presented**.**
Response: Thank you for your valid observation. We structured the paper according to the

journal's template for a policy brief. Our intention was to provide a brief summary of the underlying study before delving into the policy implications and recommendations. We deliberately excluded excessive statistical information to enhance readability for the non-academic audience. However, we have now included more data in the text figures and supplementary files.

Comment: The paper has a limited data reference list.
Response: The short reference list was to adhere to the limits of a policy brief. More references have been included in specific sections. Pages 3,5,6,7,14

Comment: Abstract mentions CKDu in passing without mentioning its prevalence in certain LMIC settings. The disease CKDu in Sri Lankan and Mesoamerican settings.
Response: Thank you for your comment. There may have been a mix up. CKDu was not mentioned in the abstract.
-

Competing Interests: None

Reviewer Report 11 September 2024

https://doi.org/10.5256/f1000research.159925.r292274

Nikola M Pavlović
[1] University of Niš, Niš, Serbia
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[3] University of Niš, Niš, Serbia

Ambient Air Pollution and Chronic kidney disease risk in Deltan communities: A Policy Brief, 2023.
Abstract

- **Comments:**
  - The abstract effectively highlights the importance of the study by addressing an issue that is often overlooked: CKD in developing countries. However, it could refine its focus on the study's objectives, methods, key findings, and specific policy recommendations.
- **Suggestions:**
  - **Objective Clarification:** Include a brief statement that clearly outlines the study's objective.
  - **Methodology Mention:** Explicitly mention that a mixed-methods approach was used.
  - **Specific Findings:** Highlight specific data points, such as the exact levels of pollutants that exceed WHO limits.

- **Policy Recommendations:** Summarize one or two key policy recommendations for a clear takeaway.

Introduction

- **Comments:**
  - The introduction is comprehensive, providing a strong background on CKD and air pollution, particularly in the context of developing countries. However, it somewhat repeats itself by discussing traditional CKD risk factors.
- **Suggestions:**
  - **Streamlining:** Consider consolidating the discussion on traditional CKD risk factors to avoid redundancy.
  - **Focused Transition:** Ensure a smooth transition from discussing CKD globally to the specific context of the Niger Delta.
  - **Identification of Gap:** Introduce the research gap on the link between air pollution and CKD in the Niger Delta earlier in the section.

Policy Outcomes and Implications

- **Comments:**
  - This section succinctly outlines the critical issue of lacking renal care policies in Nigeria. However, the link between CKD and air pollution could be articulated more forcefully to emphasize urgency.
- **Suggestions:**
  - **Direct Link:** Explicitly connect the absence of CKD in national health policy to the study's findings on air pollution and CKD prevalence.
  - **Broader Implications:** Discuss the broader public health implications if this policy gap continues, including potential long-term consequences.

Evidence of High Ambient Air Pollutant Levels in Warri

- **Comments:**
  - This section is rich in data and provides a clear picture of pollution levels. The use of a table to present hazard quotients is effective, but the narrative could be enhanced for better flow and readability.
- **Suggestions:**
  - **Narrative Flow:** Integrate the table with the narrative by referencing key figures directly in the text.
  - **Benchmark Against Global Standards:** Briefly compare the findings with global or regional averages for context.
  - **Graphical Representation:** Consider using a graph to visualize the levels of pollutants across communities for greater impact.

High Prevalence of CKD and the Risk Factors

- **Comments:**
  - This section effectively presents prevalence data and associated risk factors. The statistical significance is clearly noted, strengthening the findings.
- **Suggestions:**
  - **Risk Factor Hierarchy:** Present the risk factors in order of their strength of association with CKD.
  - **Visual Aids:** While the current figure is useful, additional visual aids, such as bar charts or scatter plots, could further clarify the distribution of CKD stages across communities.
  - **Contextualization:** Briefly contextualize the CKD prevalence data with national or regional statistics to highlight the severity.

Social Determinants of CKD Risk
- **Comments:**
  - The social determinants are well-captured, providing a comprehensive picture of contributing factors. However, the section could benefit from a more concise presentation.
- **Suggestions:**
  - **Condensation:** Consider condensing the list of behavioral factors by grouping similar items, such as unhealthy dietary habits.
  - **Clearer Connections:** Draw clearer connections between these social determinants and the higher CKD prevalence, emphasizing the compounding effect of multiple risk factors.
  - **Implications:** Discuss the potential public health implications of these social determinants in more depth.

Low Air Pollution Health Risk Literacy in Warri
- **Comments:**
  - This section addresses an important issue but could be more impactful if it connected low health literacy directly with CKD prevalence.
- **Suggestions:**
  - **Direct Linkage:** Explicitly link low literacy levels to poor health outcomes, particularly in the context of CKD and air pollution.
  - **Awareness Campaigns:** Suggest potential public health campaigns or educational interventions to improve awareness based on the findings.

Implications for Policy
- **Comments:**
  - This section provides a strong call to action. The identified policy gaps are critical and well-presented.
- **Suggestions:**
  - **Structured Recommendations:** Present the policy implications in a more structured format, possibly using bullet points or numbered lists for clarity.
  - **Evidence Integration:** Integrate specific study findings more directly into the policy recommendations to strengthen the argument for immediate action.

Actionable Recommendations
- **Comments:**
  - The recommendations are comprehensive and relevant but could be more prioritized or categorized.
- **Suggestions:**
  - **Prioritization:** Consider categorizing the recommendations into short-term, medium-term, and long-term actions.
  - **Stakeholder Engagement:** Emphasize the role of specific stakeholders (e.g., government, NGOs, the public) in implementing these recommendations.
  - **Feasibility:** Briefly discuss the feasibility of these recommendations, particularly in the context of existing infrastructure and resources.

Limitations of the Study
- **Comments:**
  - The limitations are transparently discussed, which is commendable. However, there is a risk that some of these might overshadow the study's strengths.
- **Suggestions:**
  - **Strengths Emphasis:** Counterbalance the limitations with a brief discussion of the

study's strengths, particularly its novel approach and the involvement of citizen scientists.
    - **Future Directions:** Suggest specific areas for future research that could address these limitations, enhancing the study's impact.

Conclusion

- **Comments:**
    - The conclusion effectively summarizes the key points but could be more emphatic in calling for urgent action.
- **Suggestions:**
    - **Stronger Call to Action:** End with a more forceful call to action directed at policymakers, highlighting the urgency of addressing CKD in the Niger Delta.
    - **Summary of Key Points:** Briefly summarize the most critical findings and recommendations to leave a lasting impression.

Overall Document Comments:

- **Consistency:** Ensure consistency in the use of terms (e.g., CKD vs. chronic kidney disease) throughout the document.
- **Clarity:** While the document is generally clear, some sections, particularly those with dense data, could benefit from simpler language and clearer transitions.
- **Visual Aids:** Consider the strategic use of additional visual aids to break up text-heavy sections and improve reader engagement.
- **Proofreading:** A thorough proofreading is recommended to correct any minor grammatical errors and ensure a polished final submission.

I believe these suggestions will assist the authors in refining their policy brief to make it more impactful and ensure it effectively communicates the urgency of the issue to both policymakers and the broader public.

Does the paper provide a comprehensive overview of the policy and the context of its implementation in a way which is accessible to a general reader?

Yes

Is the discussion on the implications clearly and accurately presented and does it cite the current literature?

Yes

Are the recommendations made clear, balanced, and justified on the basis of the presented arguments?

Yes

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 08 May 2024

https://doi.org/10.5256/f1000research.159925.r268338

?

Chao Yang
[1] Peking University, Beijing, Beijing, China
[2] Peking University, Beijing, Beijing, China
[3] Peking University, Beijing, Beijing, China

This study provides insights into the association between air pollution and CKD risk in Niger Delta communities. Comprehensive policy interventions and public education are needed to mitigate the CKD risk and improve overall health outcomes in these communities. Here are several specific comments for the paper:

1) The authors should provide a more detailed description of the mixed-methods approach used in the study. Clarify the specific quantitative and qualitative methods employed, sample sizes, and data collection techniques.

2) The paper mentions that air pollutant concentrations were measured and compared to WHO limits. However, the analysis of these data and their statistical significance is lacking. The authors should include a more thorough analysis of the air pollution data.

3) The paper discusses the association between ambient air pollution and CKD risk, but does not claim causality. The authors should clarify this distinction and discuss potential confounders or alternative explanations for the observed association.

4) The paper should acknowledge other limitations of the study, such as sample size, data availability, or methodological constraints. Additionally, the authors should discuss potential directions for future research to build upon the current findings.

5) The authors should discuss the generalizability of their findings to other communities and regions with similar industrial activities.

Does the paper provide a comprehensive overview of the policy and the context of its implementation in a way which is accessible to a general reader?
Partly

Is the discussion on the implications clearly and accurately presented and does it cite the current literature?
Partly

Are the recommendations made clear, balanced, and justified on the basis of the presented arguments?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 17 Jun 2024

Ogochukwu Okoye

Thank you for your kind critique of the manuscript.
All your comments are valid and appreciated. Being a policy brief, the manuscript was intentionally shortened to provide the basic information in a simple way for the intended audience, which includes policy makers.

More detailed Original manuscripts for a scientific audience have been written and are currently undergoing peer review. However, the link to the Study Thesis was provided with this submission.

Thank you.

Competing Interests: None

Author Response 30 Sep 2024

Ogochukwu Okoye

REVIEWER 1

We are grateful for your detailed and constructive critique which has helped to significantly improve the merit and quality of our manuscript

1) **The authors should provide a more detailed description of the mixed-methods approach used in the study. Clarify the specific quantitative and qualitative methods employed, sample sizes, and data collection techniques.**
Thank you for your observations. Extensive methodological and statistical details were deliberately omitted as the manuscript was targeted at policymakers. However, we have provided additional details in the text.
The underlying study was **an exploratory mixed methods study with an embedded citizen science inquiry**. Details of the first strand which was a focus group has been published and we have provided a reference to the article. In the current brief, we focus on findings from the other strands of the study.
(Pages 2,3,5)

2) **The paper mentions that air pollutant concentrations were measured and compared to WHO limits. However, the analysis of these data and their statistical significance is lacking. The authors should include a more thorough analysis of the air**

pollution data.
For the reasons mentioned above, we omitted these details. However, some additional data have been provided in the text and as supplementary files.
(Page 5, suppl 1, Figure 1)

3) **The paper discusses the association between ambient air pollution and CKD risk, but does not claim causality. The authors should clarify this distinction and discuss potential confounders or alternative explanations for the observed association.**
We agree with your observations. We have provided details of confounding factors considered and a supplementary file containing updated results from a binary mixed effects logistic model conducted to account for clustering effects.

We report that long-term exposure to ambient air pollution is associated with CKD risk, but does not independently increase its risk, after adjusting for clustering effects and confounders (age, gender, hypertension, level of education and diabetes).
(Page 6, suppl 2)

4) **The paper should acknowledge other limitations of the study, such as sample size, data availability, or methodological constraints. Additionally, the authors should discuss potential directions for future research to build upon the current findings.**

The section on limitation of the study has been improved and **suggestions for future research as follows**:

"More research is required from under-served areas to explore: this exposure-effect relationship, the mechanism of air pollution associated CKD and potential interventions to reverse it; and to develop educational interventions that would effectively improve public awareness of environmental health risks".
(Page 11)

5) **The authors should discuss the generalizability of their findings to other communities and regions with similar industrial activities.**

This has been included.
"…. our findings are generalisable to similar vulnerable populations across the globe who reside near point emission sources" (Page 7)

Competing Interests: No competing interests were disclosed.