Prospects of emerging low-cost sensors for bridging air pollution epidemiologic evidence gaps in Africa

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Figure 1. Global ranking of risk factors by total number of deaths from all causes for all ages and both sexes in 2017.

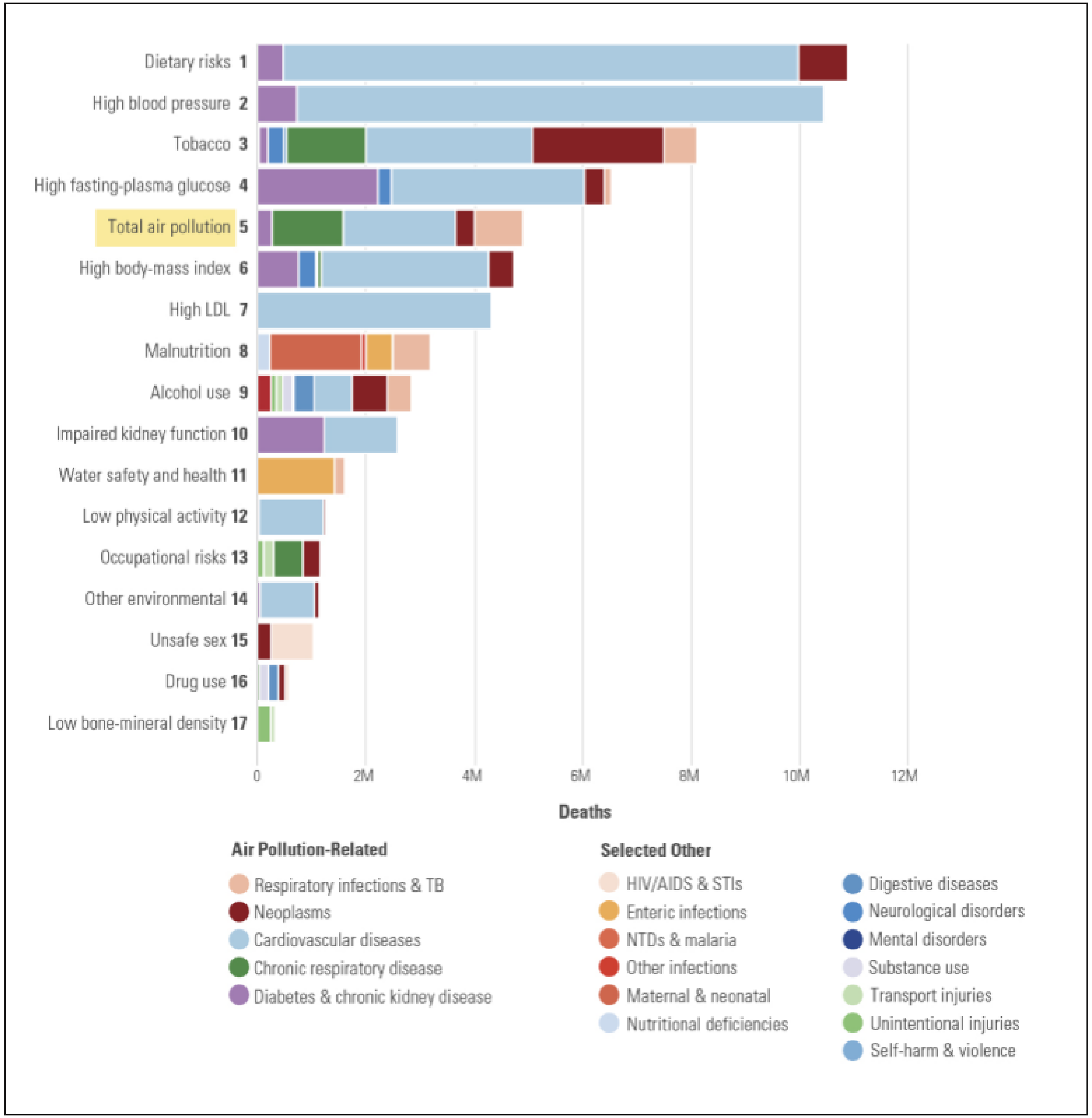
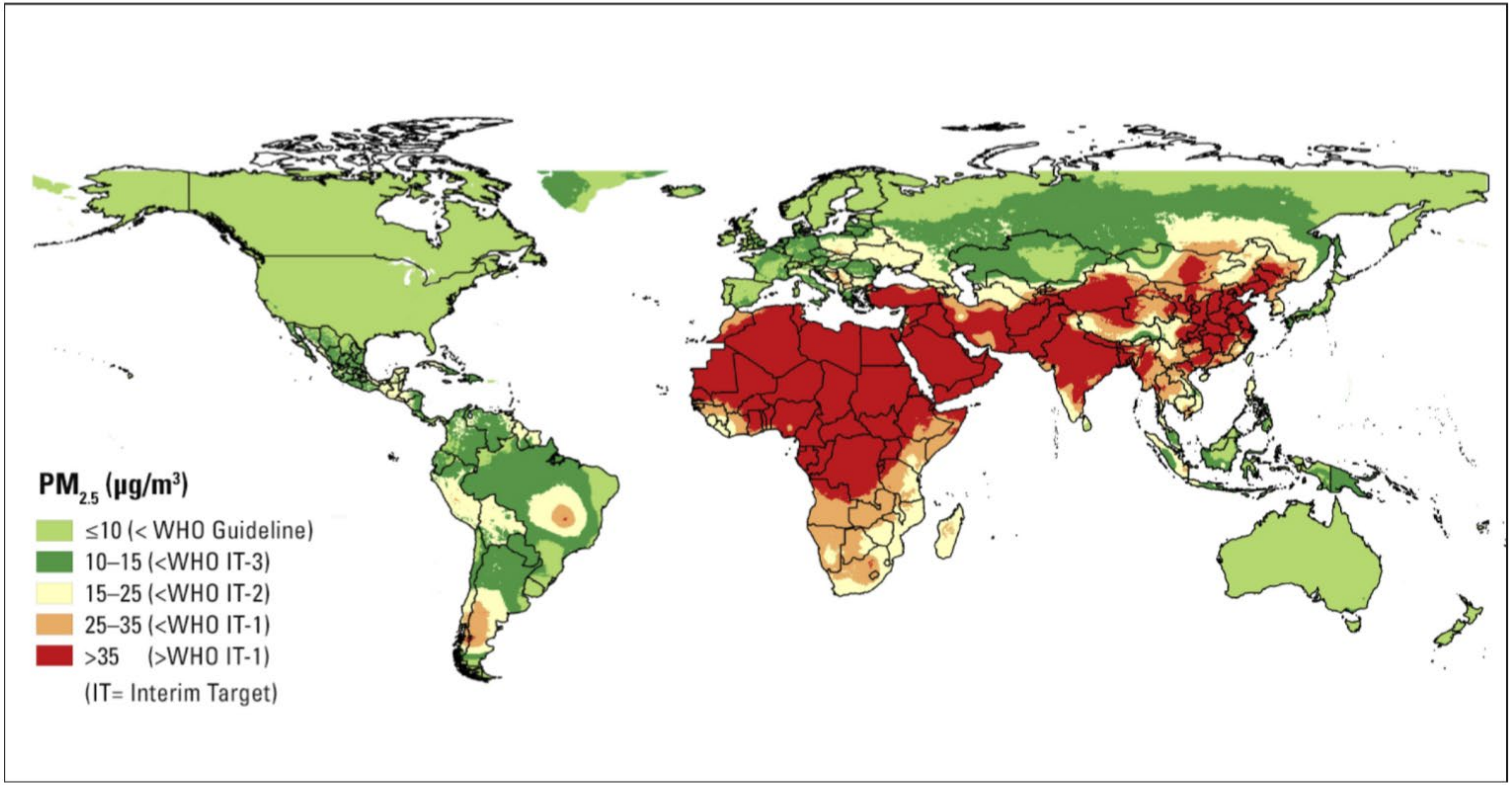
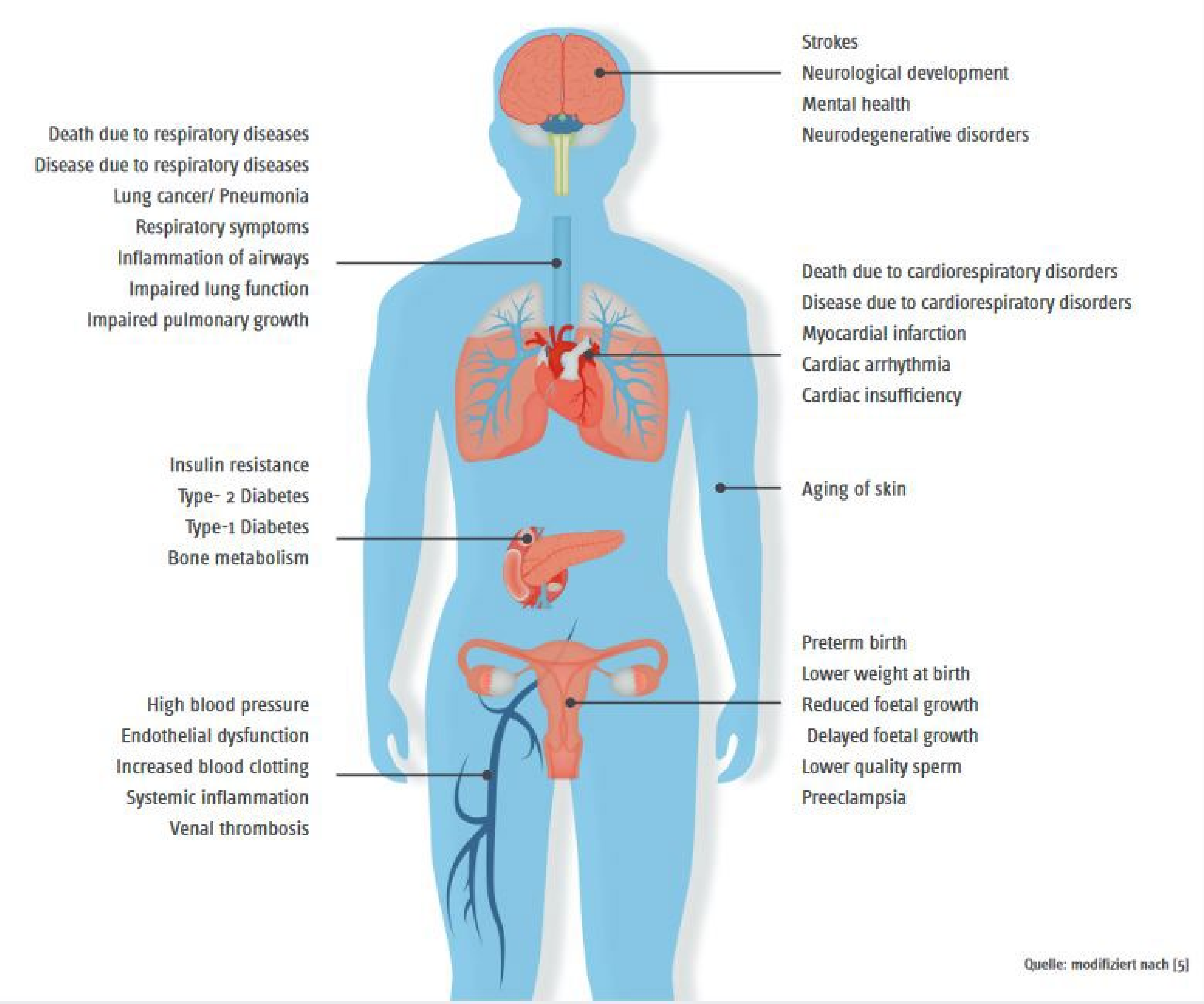


Figure 2. Annual average $PM_{2.5}$ concentrations in 2017 relative to the WHO Air Quality Guideline.




Strokes
Neurological development
Mental health
Neurodegenerative disorders
Death due to respiratory diseases
Disease due to respiratory diseases
Lung cancer/ Pneumonia
Respiratory symptoms
Inflammation of airways
Impaired lung function
Impaired pulmonary growth
Death due to cardiorespiratory disorders
Disease due to cardiorespiratory disorders
Myocardial infarction
Cardiac arrhythmia
Cardiac insufficiency
Insulin resistance
Type- 2 Diabetes
Type-1 Diabetes
Bone metabolism
Aging of skin
Preterm birth
Lower weight at birth
Reduced foetal growth
Delayed foetal growth
Lower quality sperm
Preeclampsia
High blood pressure
Endothelial dysfunction
Increased blood clotting
Systemic inflammation
Venal thrombosis
Quelle: modifiziert nach [5]


AIR POLLUTION – THE SILENT KILLER
Every year, around
7 MILLION DEATHS
are due to exposure from both outdoor and household air pollution.
Air pollution is a major environmental risk to health. By reducing air pollution levels, countries can reduce:
Stroke
Heart disease
Lung cancer, and both chronic and acute respiratory diseases, including asthma
REGIONAL ESTIMATES ACCORDING TO WHO REGIONAL GROUPINGS:
Over 2 million
in South-East Asia Region
Over 2 million
in Western Pacific Region
Nearly 1 million
in Africa Region
About 500 000
deaths in Eastern Mediterranean Region
About 500 000
deaths in European Region
More than 300 000
in the Region of the Americas
CLEAN AIR FOR HEALTH
#AirPollution
World Health Organization

Figure 9. Numbers of deaths attributable to air pollution in countries around the world in 2017.

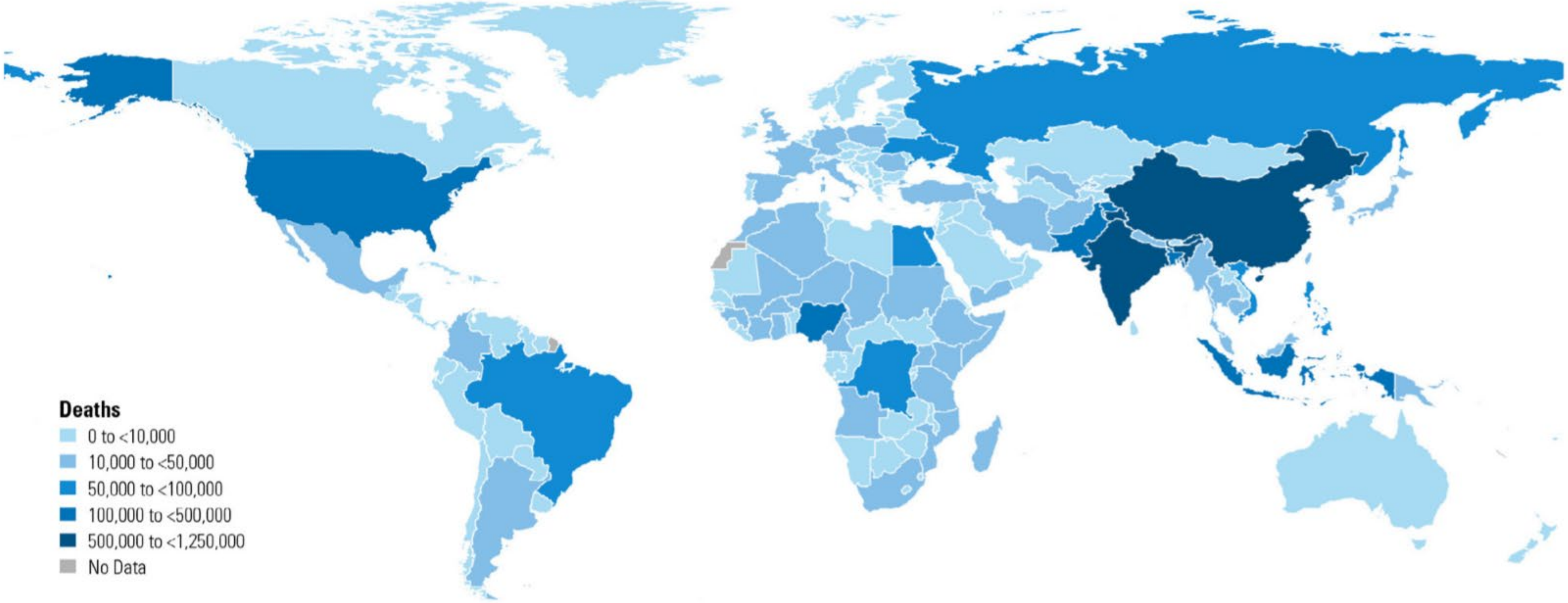
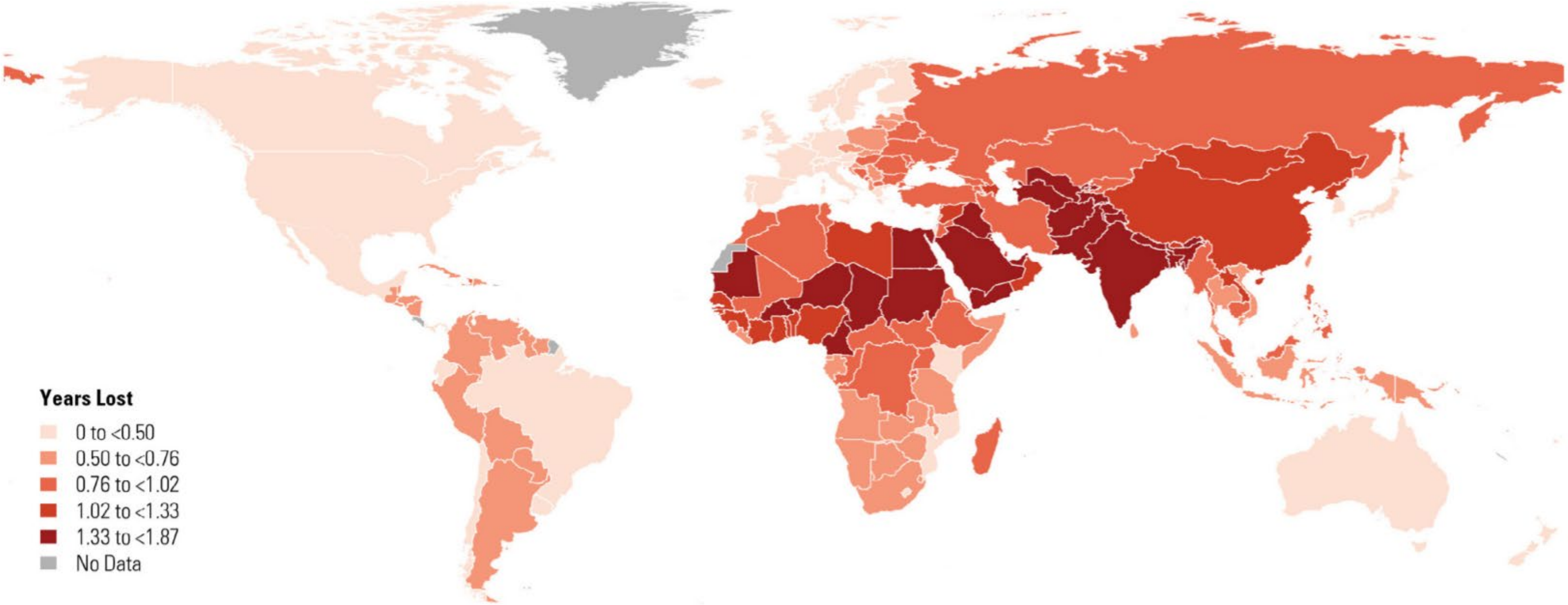


Figure 15. Global map of life expectancy loss attributable to existing levels of $PM_{2.5}$ exposure in 2016.



OECD DEVELOPMENT CENTRE

Working Paper No. 333

Research area: African Economic Outlook

The cost of air pollution in Africa

Rana Roy

Air pollution kills 712,000 people a year prematurely, compared with approximately 542,000 from unsafe water, 275,000 from malnutrition and 391,000 from unsafe sanitation.

Table 2 | Top 15 ranked countries of premature mortality linked to outdoor air pollution in 2010

Country	Deaths ($\times 10^3$)	Residential energy	Agriculture	Natural	Power generation	Industry	Biomass burning	Land traffic
China	1,357	**32** (**76**)	29 (7)	9 (3)	18 (7)	8 (3)	1 (2)	3 (2)
India	645	**50** (**77**)	6 (1)	11 (1)	14 (5)	7 (3)	7 (9)	5 (4)
Pakistan	111	31 (**67**)	2 (1)	**57** (23)	2 (1)	2 (2)	2 (3)	3 (3)
Bangladesh	92	**55** (**78**)	10 (2)	0 (0)	15 (6)	7 (2)	7 (8)	6 (4)
Nigeria	89	14 (31)	1 (0)	**77** (**52**)	0 (0)	0 (0)	8 (16)	0 (0)
Russia	67	7 (18)	**43** (**26**)	1 (0)	22 (17)	8 (5)	8 (21)	11 (13)
USA	55	6 (12)	29 (17)	2 (2)	**31** (19)	6 (5)	5 (9)	21 (**36**)
Indonesia	52	**60** (**64**)	2 (0)	0 (0)	5 (3)	4 (2)	27 (29)	2 (2)
Ukraine	51	6 (13)	**52** (**32**)	0 (0)	18 (17)	9 (7)	5 (18)	10 (13)
Vietnam	44	**51** (**74**)	12 (2)	0 (0)	13 (4)	8 (3)	12 (14)	4 (3)
Egypt	35	1 (2)	3 (3)	**92** (**88**)	2 (2)	1 (1)	0 (1)	1 (3)
Germany	34	8 (17)	**45** (26)	0 (0)	13 (10)	13 (8)	1 (3)	20 (**36**)
Turkey	32	9 (**20**)	**29** (19)	15 (6)	19 (14)	11 (8)	6 (19)	11 (14)
Iran	26	1 (3)	6 (6)	**81** (**75**)	4 (4)	3 (3)	1 (2)	4 (7)
Japan	25	12 (**29**)	**38** (22)	0 (0)	17 (15)	18 (14)	5 (8)	10 (12)
World	3,297	**31** (**59**)	20 (7)	18 (11)	14 (7)	7 (3)	5 (8)	5 (5)

Columns 3–9 show contributions (%) of the seven main source categories, the leading one in bold. For details and additional countries, see Extended Data Table 3. In parentheses are shown sensitivity calculations with carbonaceous particles having a five times larger impact than inorganic aerosol compounds.

Lelieveld *et al.* Nature 2015; 525:367-371

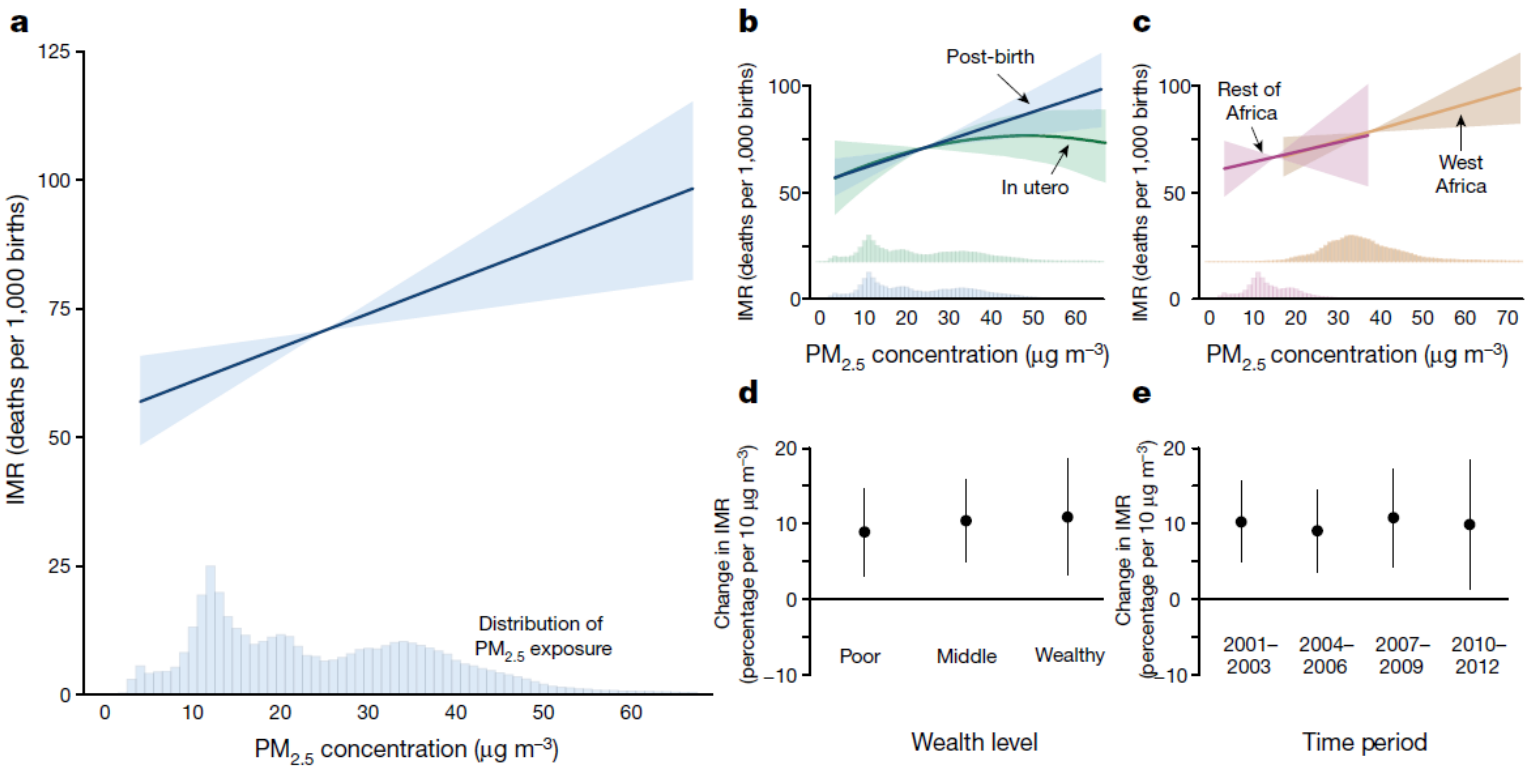


Fig. 2 | Mortality of infants in Africa is strongly and linearly increasing with post-birth $PM_{2.5}$ exposure. **a**, Effect of $PM_{2.5}$ exposure during the 12 months after birth on mortality rates of infants ($n = 990{,}696$ births). Response function is centred at mean $PM_{2.5}$ concentration (25 μg m^{-3}) and mean IMR (71 deaths per 1,000 births). Histogram shows the distribution of exposures across sample locations. **b**, Impacts of in utero versus post-birth exposures. **c**, Impacts of post-birth exposure in West Africa (higher exposure) versus the rest of Africa (lower exposure). See Extended Data Fig. 2b for countries in each region. **d**, Effect of post-birth exposure on child mortality by terciles of household-level asset wealth, measured as the percentage change in infant mortality per 10 μg m^{-3} increase in $PM_{2.5}$ exposure. **e**, Effect of post-birth $PM_{2.5}$ exposure on IMR over time, measured as the percentage change in IMR per 10 μg m^{-3} increase in $PM_{2.5}$ exposure.

Heft-Neal *et al.* Nature 2018

How reliable are GBD estimates for SSA region?

- Estimates of BOD attributable to AP in SSA are based on extrapolations of results of epidemiologic studies from locations with lower ambient PM2.5 exposures
- Very limited epidemiologic studies from Africa
- Relative contribution of specific sources of AP differ from those in North America and Europe
- IER functions are therefore limited in their application to SSA

Heft-Neal *et al.* Nature 2018

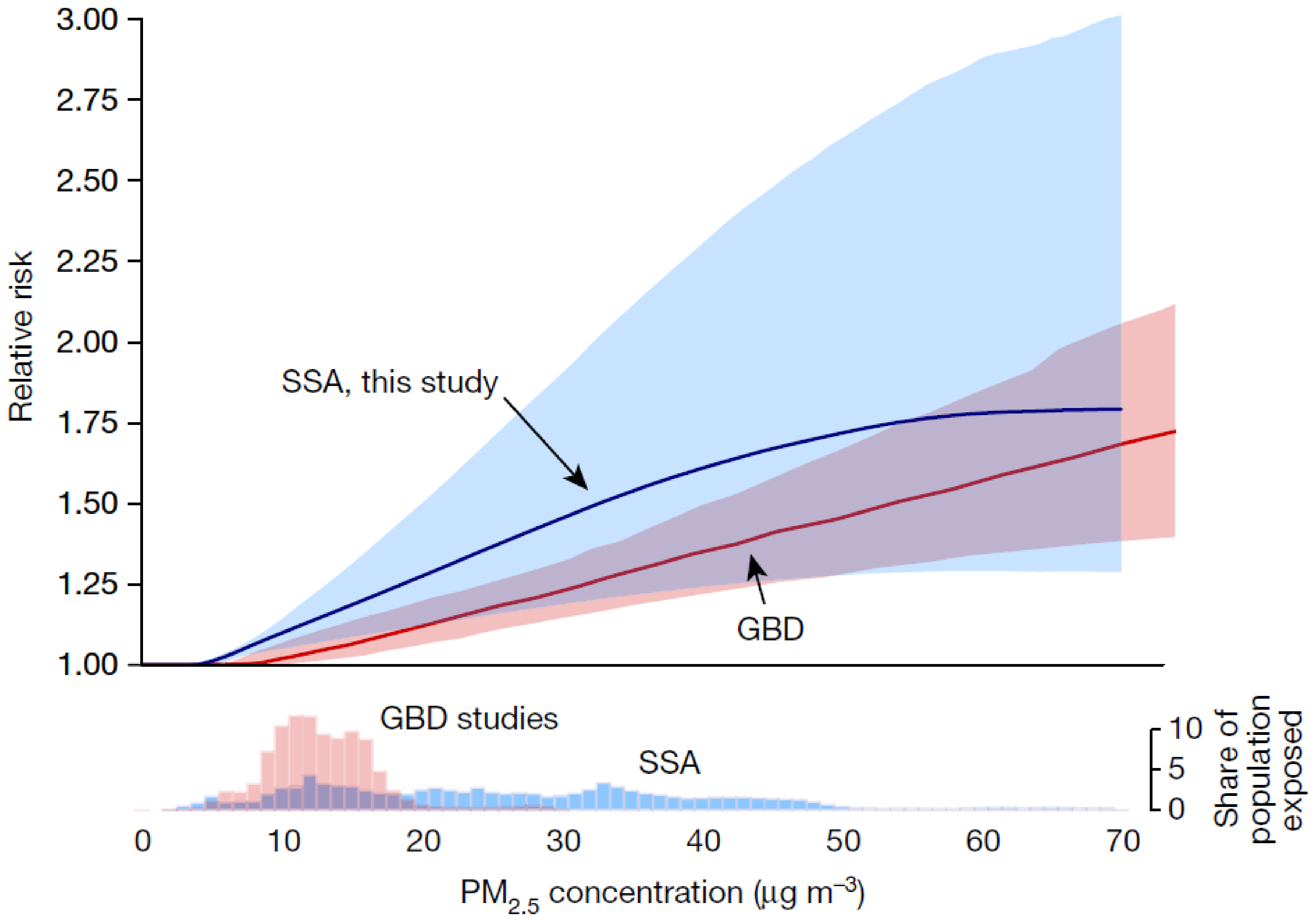


Fig. 3 | Comparing the relative risk curve for all-cause mortality from this study for SSA and the risk curve for respiratory-infection-specific mortality estimated for the Global Burden of Disease (GBD) study.

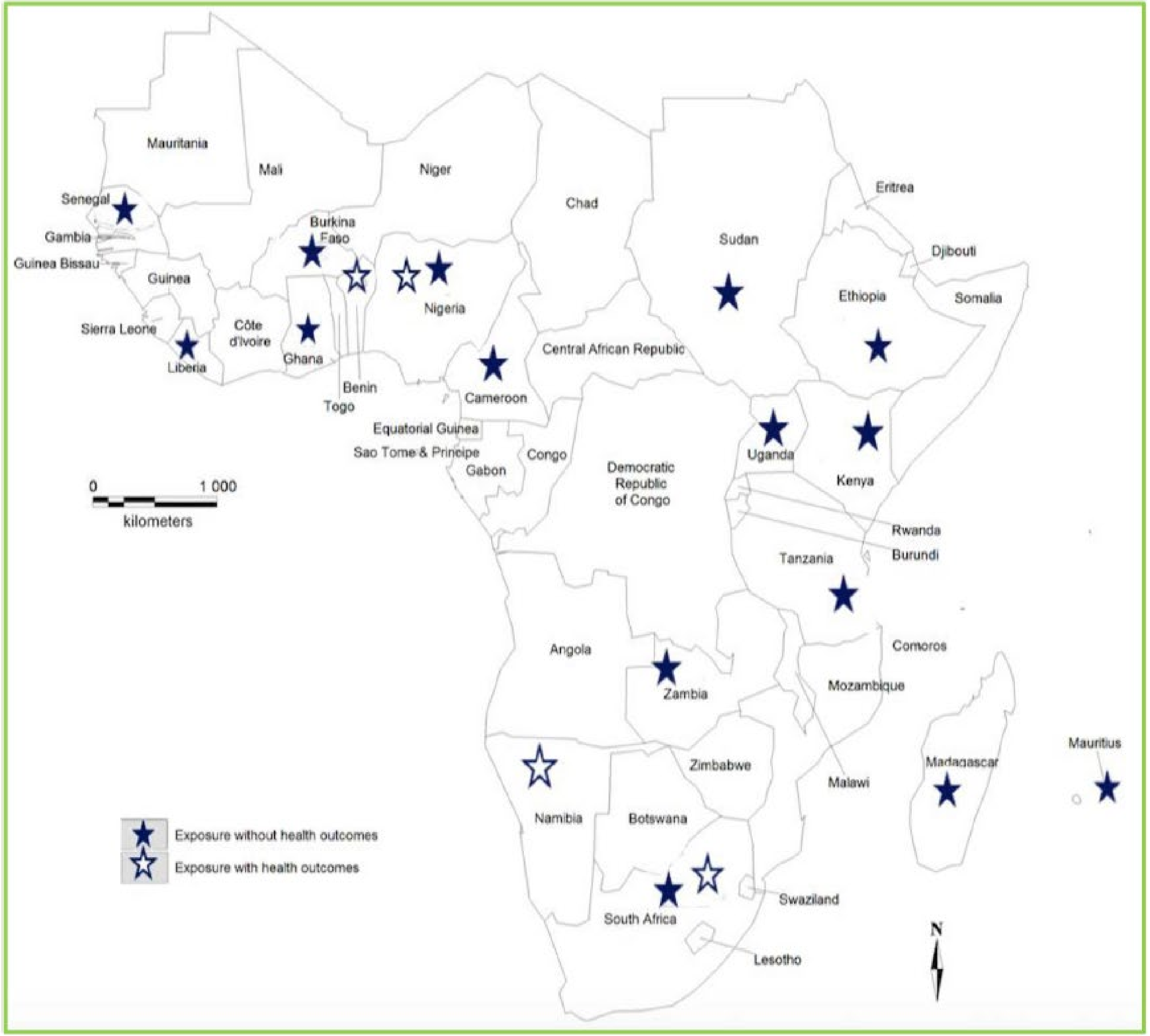


Fig. 3. Map of sub-Saharan Africa indicating countries with at least one report or study on ambient air pollution. Full symbols indicate that at least one "criteria air pollutant" was measured (e.g. PM_{10}, $PM_{2.5}$, CO, SO_2, NO_2), open symbols indicate health outcomes were also assessed. The location of the symbols within a country does not correspond to the exact location of the study; most studies were done in the country capitals or major cities.

Katoto *et al.*
Environ Res 2019;
173: 174–188

BOD attributable to ambient air pollution in SSA is growing, yet estimates of its impact on the region are underestimated due to

- lack of air quality monitoring
- paucity of air pollution epidemiological studies, and
- important population vulnerabilities in the region

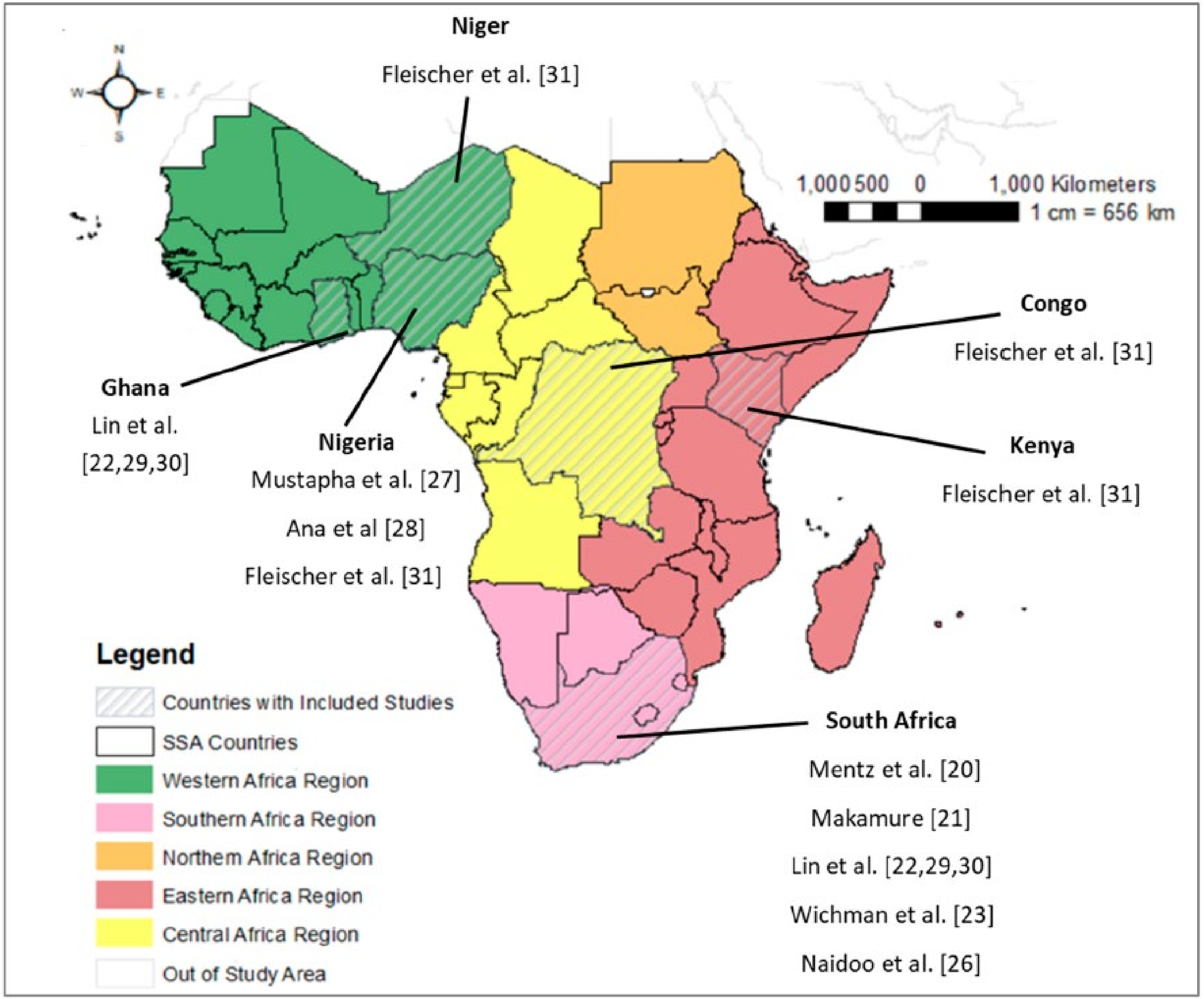


Figure 1. Map of study area and locations of individual-level AAP epidemiology studies. Countries with individual-level AAP epidemiology studies are indicated with diagonal grey lines and the respective study author and citation number provided for each studied country.

Coker & Kizito
Int J Environ Res Public Health 2018; 15: 427

Environmental Pollution 241 (2018) 1132–1137

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Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Proliferation of low-cost sensors. What prospects for air pollution epidemiologic research in Sub-Saharan Africa?☆

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expensive instrumentation for AQM as necessary for improving and protecting public health. I conclude that, in a region that is bereft of air pollution data, the growing influx of low-cost sensors represents an excellent opportunity for bridging the data gap to inform air pollution control policies and regulations for public health protection. However, it is essential that only the most promising sensor technologies that performs creditably well in the harsh environmental conditions of the region are promoted.

Strengths of LCS technologies

- Air pollution measurements at high spatiotemporal resolution is necessary for accurate assessment of both outdoor and personal exposure
- LCS can easily be deployed at several locations to increase granularity in air pollution measurement and enable better quantification of exposure.
    - Major validity concern of published air pollution epidemiologic studies
- LCS can thus complement regulatory monitoring to advance exposure science

Commentary

The Ghana Urban Air Quality Project (GHAir): Bridging air pollution data gaps in Ghana

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Air pollution has been recognized as a pressing sustainability concern seeing that it is directly mentioned in two SDG targets: SDG 3.9 (substantial reduction of health impacts from hazardous substances) and SDG 11.6 (reduction of adverse impacts of cities on people) (Rafaj et al., 2018). Air pollution, both ambient and indoor, is known to contribute significantly to the global burden of disease, contributing to a majority of non-communicable

can be leveraged to complement the limited reference-grade monitors that may be available.

It is against this background that the Ghana Urban Air Quality Project (GHAir) was established in May 2019 with the overall goal of bridging the air pollution data and epidemiologic research gap in Ghana. The objectives of the project are to: (1) develop a

ARTICLE

Particulate matter pollution at traffic hotspots of Accra, Ghana: levels, exposure experiences of street traders, and associated respiratory and cardiovascular symptoms

A. Kofi Amegah[1]✉, Gordon Dakuu[2], Pierpaolo Mudu[3] and Jouni J. K. Jaakkola[4]

BACKGROUND: There are limited studies on the health effects of street trading in spite of common knowledge that individuals engaged in the trade are exposed to high levels of traffic-related air pollution per their mode of operation, and also the fact that the venture is a dominant occupation in cities of Sub-Saharan Africa (SSA) and other developing regions.
OBJECTIVE: We characterized particulate matter (PM) pollution levels at traffic hotspots of Accra, Ghana during the dry and wet seasons, and assessed exposure experiences of street traders.
METHODS: A cross-sectional study was conducted among 236 street traders operating along six selected traffic routes of Accra and a comparison group of 186 office workers. PurpleAir PA-II monitors were used to measure PM levels at the selected traffic routes. We estimated annual $PM_{2.5}$ exposure of street traders using assigned seasonal $PM_{2.5}$ levels, and information collected in a structured questionnaire on their activity patterns. Outcomes investigated were self-reported respiratory and cardiovascular symptoms.
RESULTS: PM levels at Accra traffic hotspots were high in both seasons. 1 ug/m^3 increase in $PM_{2.5}$ exposure increased respiratory, cardiovascular, and overall symptoms by a factor of 0.00027 (95% CI: 0.00012, 0.00041), 0.00022 (95% CI: 0.00007, 0.00036), and 0.00048 (95% CI: 0.00023, 0.00073), respectively. Compared to office workers, high $PM_{2.5}$ exposure among street traders was associated with increased odds of coughing, catarrh (postnasal drip), sneezing, rapid heart beating, irregular heartbeat, sharp chest pains, fainting spells, headaches, and dizziness. Low and medium $PM_{2.5}$ exposure was associated with increased odds of dermatitis, rapid heart beating, and irregular heartbeat, and sharp chest pains, respectively.

Table 8. Binary logistic regression of respiratory and cardiovascular symptoms on annual $PM_{2.5}$ exposures ($N = 374$).

	Respiratory symptoms		Cardiovascular symptoms	
	Unadjusted OR (95% CI)	**Adjusted OR (95% CI)**	**Unadjusted OR (95% CI)**	**Adjusted OR (95% CI)**
	Coughing		Rapid heart beating	
Tertile 1	0.82 (0.44, 1.53)	1.05 (0.51, 2.17)	2.29 (1.05, 4.98)	3.23 (1.27, 8.20)
Tertile 2	1.12 (0.61, 2.03)	1.48 (0.70, 3.16)	1.30 (0.55, 3.09)	1.58 (0.55, 4.50)
Tertile 3	1.75 (0.98, 3.11)	2.21 (1.06, 4.61)	3.80 (1.83, 7.88)	3.84 (1.51, 9.77)
	Breathing difficulty		Irregular heart beat	
Tertile 1	1.58 (0.67, 3.72)	2.38 (0.88, 6.40)	1.77 (0.79, 3.99)	2.67 (1.01, 7.03)
Tertile 2	1.10 (0.43, 2.78)	1.78 (0.58, 5.46)	1.30 (0.55, 3.09)	1.72 (0.59, 5.01)
Tertile 3	1.53 (0.65, 3.60)	2.28 (0.79, 6.56)	2.57 (1.20, 5.51)	2.78 (1.04, 7.48)
	Breathing faster than normal		Sharp chest pains	
Tertile 1	1.16 (0.48, 2.81)	1.44 (0.52, 3.98)	1.18 (0.64, 2.20)	1.62 (0.79, 3.29)
Tertile 2	1.16 (0.48, 2.81)	1.47 (0.50, 4.31)	1.68 (0.92, 3.04)	2.58 (1.21, 5.49)
Tertile 3	1.88 (0.85, 4.18)	2.30 (0.85, 6.24)	1.99 (1.11, 3.57)	2.99 (1.43, 6.29)
	Catarrh		Headaches	
Tertile 1	1.42 (0.81, 2.51)	1.63 (0.83, 3.21)	0.69 (0.39, 1.21)	0.96 (0.49, 1.89)
Tertile 2	1.15 (0.66, 2.01)	1.39 (0.67, 2.89)	1.32 (0.74, 2.38)	1.95 (0.91, 4.19)
Tertile 3	2.67 (1.46, 4.90)	3.27 (1.52, 7.05)	1.75 (0.96, 3.21)	2.38 (1.10, 5.15)
	Sneezing		Dizziness	
Tertile 1	0.99 (0.57, 1.73)	1.70 (0.87, 3.31)	1.21 (0.63, 2.34)	1.67 (0.77, 3.60)
Tertile 2	0.80 (0.46, 1.41)	1.60 (0.77, 3.30)	0.97 (0.49, 1.92)	1.37 (0.59, 3.19)
Tertile 3	1.93 (1.10, 3.38)	3.70 (1.77, 7.77)	2.38 (1.29, 4.37)	3.10 (1.41, 6.83)
	Wheezing		Fainting spells	
Tertile 1	0.87 (0.35, 2.14)	1.61 (0.56, 4.62)	1.01 (0.29, 3.57)	2.17 (0.53, 8.96)
Tertile 2	0.87 (0.35, 2.14)	1.71 (0.56, 5.21)	0.49 (0.1, 2.43)	1.28 (0.21, 7.59)
Tertile 3	0.30 (0.08, 1.05)	0.51 (0.12, 2.10)	2.67 (0.98, 7.32)	6.36 (1.67, 24.28)
	Dermatitis		Hypertension	
Tertile 1	3.25 (1.28, 8.23)	3.51 (1.20, 10.22)	-	-
Tertile 2	2.12 (0.78, 5.74)	2.40 (0.73, 7.87)	0.97 (0.37, 2.55)	2.53 (0.72, 8.87)
Tertile 3	1.32 (0.44, 3.94)	1.52 (0.43, 5.36)	0.73 (0.27, 2.02)	1.39 (0.38, 5.08)
	Allergic rhinitis		Overweight/Obesity	
Tertile 1	2.44 (0.87, 6.84)	2.43 (0.67, 8.77)	0.38 (0.20, 0.74)	0.63 (0.28, 1.41)
Tertile 2	1.28 (0.39, 4.18)	1.06 (0.24, 4.67)	0.88 (0.49, 1.57)	1.44 (0.63, 3.30)
Tertile 3	1.79 (0.61, 5.32)	1.27 (0.32, 5.09)	1.10 (0.63, 1.94)	1.25 (0.55, 2.81)

Madina Zongo Junction
Atomic Junction
Route 4
Okponglo Intersection
Shiashie
Accra Mall Round About
Tetteh Quarshie Interchange
Dzowrlu Intersection
Route 2
Route 6
Lapaz Traffic Light
Roman Ridge
Nyamekye Traffic Light
Kwashieman Intersection
37 Intersection
Awoshie Intersection
Odorkor Traffic Light
Sensor locations
Ring Road Central
Route 1
Kaneshie First Light
Danquah Circle
Kaneshie Mpamprom
Adabraka Market Area
Graphic Road
Circle
Route 3
Oxford Street
Barnes Road, Accra Central
Swanzy Arcade
Accra City Hall
CMB
Route 5
Makola

Local News

AMA engages community leaders, traders, vendors on air quality

The Accra Metropolitan Assembly (AMA) has held a one-day stakeholder engagement for community leaders, traders and vendors on urban health initiative aimed at improving air quality in the city.

The essence of the engagement was to help reduce air pollution-related diseases such as lung disorders, stroke and blood pressure, which had been on the increase in recent years, explain the assembly's waste segregation programme, as well as the effects of air pollution and its health impacts on city dwellers.

Speaking at the event at the City Hall in Accra, Mr Desmond Appiah, the Chief Sustainability Advisor to the Mayor of Accra, Mohammed Adjei Sowah, said the assembly decided to bring together stakeholders who were vulnerable to poor air quality and whose actions may be leading to pollution in the air to appreciate the consequences of air pollution.

"This project has been going on for about a year now; we have engaged selected communities, churches, schools, among others, and today we believe that it was right to bring together street vendors, informal waste collectors and pickers, market women, as well as transport operators to have an appreciation on the sale of the challenge and what can be done about it. We think the first step is getting data and sharing the information," he said.

He reiterated that the indiscriminate burning of waste, fumes from vehicles and unclean cooking methods were a leading cause of air pollution in the city, adding that in Ghana, 1,000 people die of air pollution.

He admonished women "to adopt the use of clean cooking methods such as stoves and LPG gas in their homes, indicating that the practice would go a long way to help in the fight against air pollution."

Mr Appiah also appealed to city dwellers to desist from waste burning, and encouraged them to segregate their waste before giving them to the accredited waste collectors.

He revealed that the Environmental Protection Agency (EPA) had introduced a law to prohibit vehicles that produce fumes in the city and arrest the driver.

Dr Kofi Amegah, a senior lecturer of Epidemiology and Biostatistics at The University of Cape Coast, in a presentation on 'Air pollution in Accra City: Vulnerable Populations, Health Impacts and Interventions', said air pollution was a major environmental risk to health, and by reducing air pollution levels, countries could reduce health conditions such as strokes, heart disease and lung cancer, among others.

He said major sources of air pollution in Accra were vehicular emissions, industrial emissions, resuspended road dust, emissions from landfill sites, power generation plants, use of solid fuels for domestic and commercial cooking, and solid waste burning at home.

He disclosed that 7 million people die prematurely every year from air pollution, adding that among these deaths, 34 per cent, 21 per cent and 20 per cent were from Ischaemic heart diseases, pneumonia and strokes respectively.

He said 19 per cent of the deaths associated with air pollution were also from chronic obstructive pulmonary disease (COPD) while 7 per cent were from lung cancer.

He pointed out that air pollution was the presence of substances in the atmosphere that were harmful to the health of humans and other living beings, or cause damage to the climate or to materials, some of which, he said, could be solid particles, liquid droplets, or gases such as ammonia, carbon monoxide, sulphur dioxide, nitrous oxides, methane and chlorofluorocarbons, particulates, both organic and inorganic biological molecules.

He noted that it was the responsibility of every individual to ensure the cleanliness of the city, and appealed to drivers to also service their vehicles regularly to reduce pollution.

"I would like to advise that we patronise public transport, ride bicycles and use Liquefied Petroleum Gas (LPG) instead of using firewood," he said.

This engagement forms part of the Urban Health Initiative's BreatheLife Accra project, which is in collaboration with the World Health Organisation (WHO), with support from the Climate and Clean Air Coalition (CCAC).

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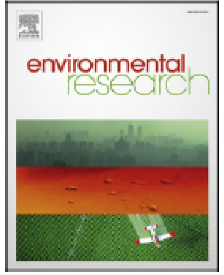

A land use regression model using machine learning and locally developed low cost particulate matter sensors in Uganda

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ABSTRACT

The application of land use regression (LUR) modeling for estimating air pollution exposure has been used only rarely in sub-Saharan Africa (SSA). This is generally due to a lack of air quality monitoring networks in the region. Low cost air quality sensors developed locally in sub-Saharan Africa presents a sustainable operating mechanism that may help generate the air monitoring data needed for exposure estimation of air pollution with LUR models. The primary objective of our study is to investigate whether a network of locally developed low-cost air quality sensors can be used in LUR modeling for accurately predicting monthly ambient fine particulate matter (PM2.5) air pollution in urban areas of central and eastern Uganda. Secondarily, we aimed to explore whether the application of machine learning (ML) can improve LUR predictions compared to ordinary least squares (OLS) regression. We used data for the entire year of 2020 from a network of 23 PM2.5 low-cost sensors located in urban municipalities of eastern and central Uganda. Between January 1, 2020 and December 31, 2020,

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MDPI

Article

Measuring Air Quality for Advocacy in Africa (MA3): Feasibility and Practicality of Longitudinal Ambient $PM_{2.5}$ Measurement Using Low-Cost Sensors

Babatunde I. Awokola [1,2,3,*,†], Gabriel Okello [4,5,†], Kevin J. Mortimer [2,6], Christopher P. Jewell [1], Annette Erhart [7] and Sean Semple [8]

Purple Air-II-SD sensors. Despite some operational challenges, this study demonstrated that it is reasonably practicable and feasible to establish a network of low-cost devices to provide data on local $PM_{2.5}$ concentrations in SSA countries. Such data are crucially needed to raise public, societal and policymaker awareness about air pollution across SSA.

Association between $PM_{2.5}$ and respiratory hospitalization in Rio Branco, Brazil: Demonstrating the potential of low-cost air quality sensor for epidemiologic research.

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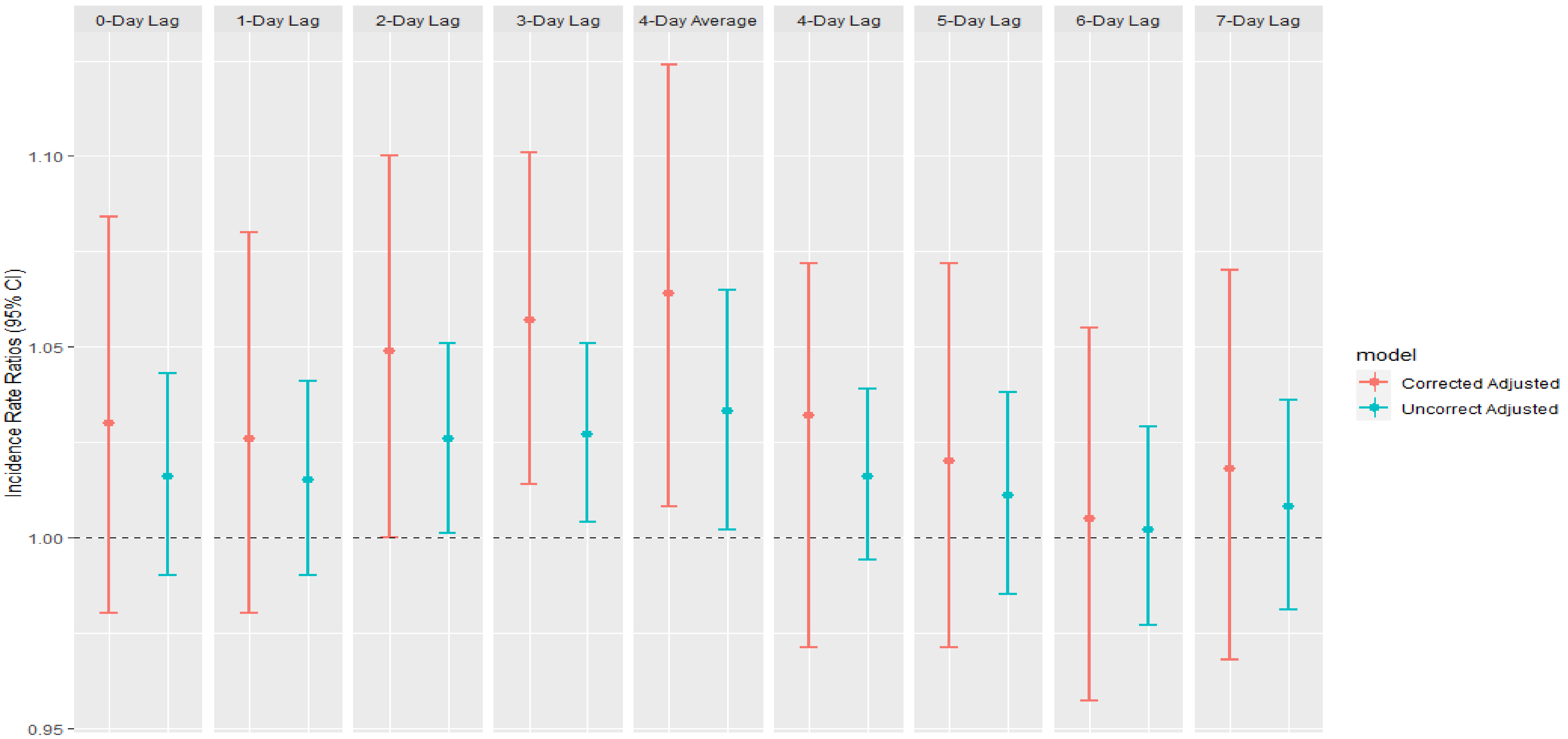
- We investigated the potential of PurpleAir sensors for conducting air pollution epidemiologic research leveraging on the USEPA US-wide correction formula for ambient PM2.5
- We used data from a PurpleAir sensor located in Rio Branco, Brazil between 2018 and 2019.
- Humidity measurements from the PurpleAir sensor were used to correct the PM2.5 concentrations.
- We established the relationship between ambient PM2.5 (corrected and uncorrected) and daily all-cause respiratory hospitalization in Rio Branco, Brazil using GAM and DLNM



Adjusted incidence rate ratios (IRR) for a 10-unit increase of corrected (red) and uncorrected (blue) PM2.5 concentrations.

- We observed increases in daily respiratory hospitalizations of 4.9% (95% CI: 1.4%, 10.1%) for a 2-day lag and 5.7% (95% CI: 1.4%, 10.1%) for 3-day lag, per 10µg/m3 PM2.5 (corrected values).
- Exposure-response relationships estimated using corrected low-cost air quality sensor data were comparable with relationships estimated using reference grade monitors and validated air quality modelling approaches
  - Suggests that correcting low-cost PM2.5 sensor data may mitigate bias attenuation in air pollution epidemiologic studies.

Conclusion

- In SSA, in the short to medium term, LCS should be leverage over the prohibitively expensive regulatory and reference instrumentation
- In the long-term, investment in regulatory instrumentation, no matter how limited they will be, is recommended for periodically calibrating sensor networks and developing correction factors
  - Helps to address data quality issues and inspire public confidence in the policies and regulations, and research findings emanating from such air pollution data.

Session Q&A Discussion

Please submit your questions for the session speakers through Whova – on your mobile or desktop device.

Make sure to note WHOM your question should be addressed to.

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Thank You for joining us for Part 1 of the session.

Part 2 will begin momentarily.

Part 2 Speakers:

Emmanuel Appoh, *Ghana Environmental Protection Agency*

Sandra Freire, *University of Cabo Verde*

Tom Grylls, *Clean Air Fund*

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