Air Pollution in The Gambia: Insights from a 12-Month Low-Cost Air Quality Sensor Network

National Environment Agency Republic of The Gambia

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Executive Summary

Overview of the Report

The Gambia National Environment Agency (NEA), in partnership with the Permian Health Lung Institute, launched a Clean Air Initiative in June 2023 to address air pollution in the country. This initiative involved deploying an integrated network of low-cost air quality sensors across strategic locations, including Brikama, Brusubi, Kanifing, and Tanji. Spanning a 12-month data collection period from June 2023 to June 2024, the initiative aimed to provide a comprehensive overview of PM2.5 concentrations, which have significant health implications.

Key Findings

The first-year results indicated a stark seasonal variation in PM2.5 levels, with higher concentrations during the dry Harmattan season and lower levels in the rainy season. Specifically, the annual mean concentration of PM2.5 was 36.9 $\mu g/m^3$, far exceeding the WHO guideline of 5 $\mu g/m^3$. Tanji emerged as a significant pollution hotspot, primarily due to intense fish processing activities. Health data from nearby facilities indicated that while PM2.5 levels showed limited direct impact on respiratory conditions like asthma and pneumonia, urban areas had significantly higher rates of these conditions compared to rural areas. This disparity underscores the need for targeted public health interventions to better understand and mitigate urban-rural differences in health outcomes.

Recommendations and Future Directions

The NEA will expand its air quality sensor network and install a reference-grade monitor in fiscal year 2025, enabling the agency will produce annual air quality reports to inform policies and establish interim PM2.5 targets. Training local staff in atmospheric science is crucial for sustainability. NEA will collaborate with the Ministry of Health and stakeholders to raise public awareness about air pollution, especially during high-risk periods like the Harmattan season. A key national agenda is transitioning from firewood, charcoal, and fossil fuels to renewable, cleaner energy in The Gambia. Working with the Ministry of Petroleum and Energy, NEA will share data and best practices for alternative energy sources.

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Acknowledgements

This report was written by staff of the National Environment Agency (NEA). Additional data contributions and authorship are attributed to Dr. Buba Manjang, Director of Public Health Services, Directorate of Public Health Services, Ministry of Health, Sunkaru Touray, MD, FACP, FCCP, Julius O. David, and Awa Sabally Touray, MD of the Permian Health Lung Institute, with support from a Clean Air Award granted by the University of Chicago Energy Policy Institute (EPIC) .

Background

Air pollution remains a leading global cause of mortality, accounting for 8.1 million deaths annually and is an established risk factor for noncommunicable diseases (NCDs), which were responsible for 34% of adult deaths in The Gambia in 2019.[1–3] Despite these significant health implications, data on air quality, specifically ultrafine particulate matter (PM2.5), are limited in The Gambia due to inadequate infrastructure and expertise for precise measurement. The absence of a reference-grade monitoring system further hinders the establishment of standards and policies necessary for public health protection. As part of the National Environment Agency's effort to improve air quality monitoring and environmental protection, the agency partnered with Permian Health Lung Institute (PHLI) to implement a Clean Air Initiative aimed at addressing this critical data gaps in the country. Since June 2023, the NEA and PHLI have deployed an integrated network of low-cost air quality sensors across various locations in The Gambia (Figure 1) which continuously measure ambient particulate matter (PM 2.5), temperature, and humidity continuously in a retrievable format. This report presents long-term PM2.5 data collected over a 12-month period from strategically selected sites in the Greater Banjul Area (GBA).

Air Quality Network Development and Installation

Following a thorough evaluation of low-cost sensors available on the market and based on their performance characteristics compared to reference-grade monitors evaluated at AFRICET in Ghana, IQAir AirVisual Outdoor sensors were selected for deployment. These sensors were installed at four locations in The Gambia: Brikama, Brusubi, Kanifing, and Tanji. Site selection criteria included high population density, security, and the ability to obtain installation permissions from relevant authorities (Figure 1).

Figure 1: *Air Quality Sensor installations in The Gambia.*

The sensors are powered by solar panels equipped with 12V rechargeable batteries to ensure a continuous power supply. Data transmission was facilitated via 4G LTE cellular SIM cards, which sent the collected data to the cloud-based AirVisual Platform. Data collection spanned from June 2023 to June 2024 and included measurements of PM 2.5 in micrograms per cubic meter (µg/m^3), temperature in degrees Celsius (°C), and relative humidity in percentage (%).

The dataset was subsequently exported and analyzed using STATA software. Analysis focused on computing the 12-month and seasonal average PM 2.5 concentrations, with the dry season defined as November to May and the rainy season from June to October.

Air Quality Sensors in The Gambia	
Location	**Region**
Brikama Nyambai	WCR
Kanifing Industrial Area	KMC
Taf City, Gunjur	WCR
Tanji	WCR
Bakoteh Dumpsite	KMC
McCarthy Square	Banjul
Gunjur Batoh Sateh	WCR
Soma	LRR
Farafenni	NBR
Brikama Ba	CRR
Basse	URR
Kartong Bird Observatory	WCR

Reference Grade Beta Attenuation Monitor Installation

On November 11th, 2024, in a groundbreaking effort, the agency, alongside the Permian Health Lung Institute, successfully installed the first reference grade beta attenuation monitor at the NEA headquarters in Kanifing. A beta attenuation monitor serves as the gold standard in air quality monitoring by measuring particulate concentrations using beta radiation attenuation, providing highly accurate and dependable environmental data crucial for health and policy decisions.

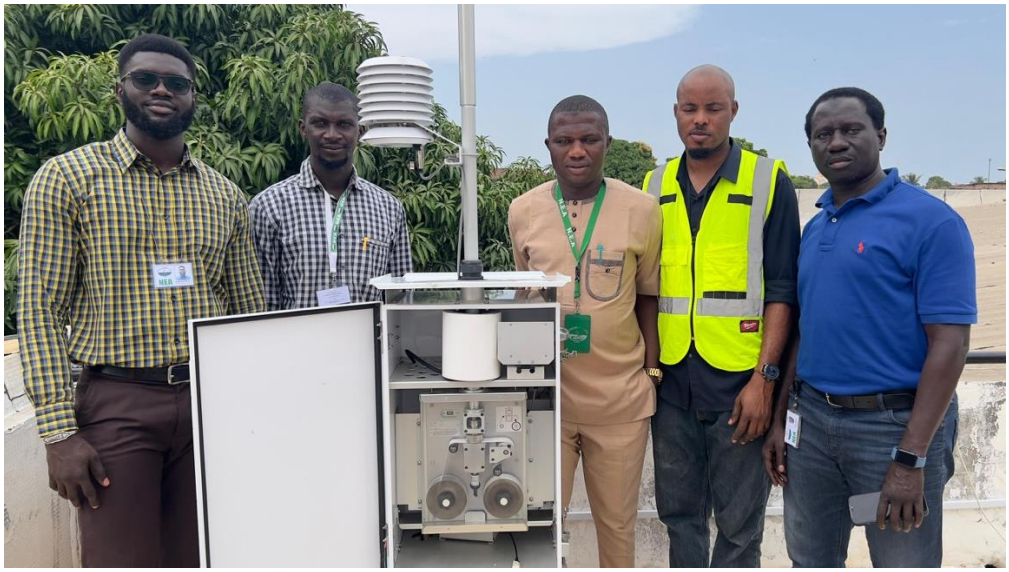

Figure 2: Installation of BAM 1022 Reference Grade Air Quality Monitor at NEA Headquarters in Kanifing, November 11th 2024

This significant milestone was made possible by the generous contributions and collaboration of the Permian Health Lung Institute and *MetOne Instruments*, a renowned device manufacturer located in Grants Pass, Oregon. The successful installation also benefitted from *Dr. Sunkaru Touray's* expertise and his connections at the US Environmental Protection Agency, which helped facilitate this achievement.

With the installation of this cutting-edge technology, The Gambia is now part of a small group of African nations boasting a dense network of both low-cost air sensors and reference grade air quality monitors. This development signals a robust enhancement in the country's capacity for environmental air quality monitoring, setting a high standard for future initiatives in the region.

Additionally, with support from the Permian Health Lung Institute and the Health Effects Institute in Boston, Massachusetts, our agency facilitated the participation of staff member *Mariatou Dumbuya* in the West African School for Air Pollution Management and Prevention at Kwame Nkrumah University of Science and Technology. This program

convened regional experts and policymakers to share best practices in air pollution monitoring and management, helping to build local capacity towards achieving our mandate to advise the National Environment Management Council on air quality and climate change.

Figure 3: Mariatou Dumbuya at the West African School for Air Pollution Prevention and Management, KNUST, Kumasi, Ghana

Moving forward, the next phase involves collaboration with local government entities, including municipal and area councils, to incorporate this valuable air quality data into their existing environmental monitoring programs. This integration will ensure that precise measurements of particulate matter and pollution levels directly influence sustainability efforts and policymaking, fostering a healthier environment for all citizens.

First year results

The 12-month mean concentration of *PM2.5 was 36.9 µg/m^3 (95% Confidence Interval: 31.9 - 42.0 µg/m^3)*. This is seven (7) higher than the most recent World Health Organization (WHO) Air Quality Guidelines (AQG) which recommend a target level of less than 5 *µg/m^3*.

Air Quality in The Gambia (4 Sensors, July 2023 – June 2024)			
	Annual Mean (Mean, 95% CI)	**Dry Season (Mean, 95% CI)**	**Rainy Season (Mean, 95% CI)**
PM 2.5 (µg/m3)	36.9 (31.9 - 42.0)	44.9 (39.7 - 50.2)	25.8 (18.6 - 32.9)
US Air Quality Index (AQI)	107 (96 - 117)	123 (112 - 134)	84 (69 - 99)

Table 1

Significant seasonal variation in particulate matter was evident, with elevated PM2.5 levels during the dry season (November to May) averaging 44.9 µg/m^3 (95% CI: 39.7 - 50.2 µg/m^3), compared to 25.8 µg/m^3 (95% CI: 18.6 - 32.9 µg/m^3) during the rainy season.

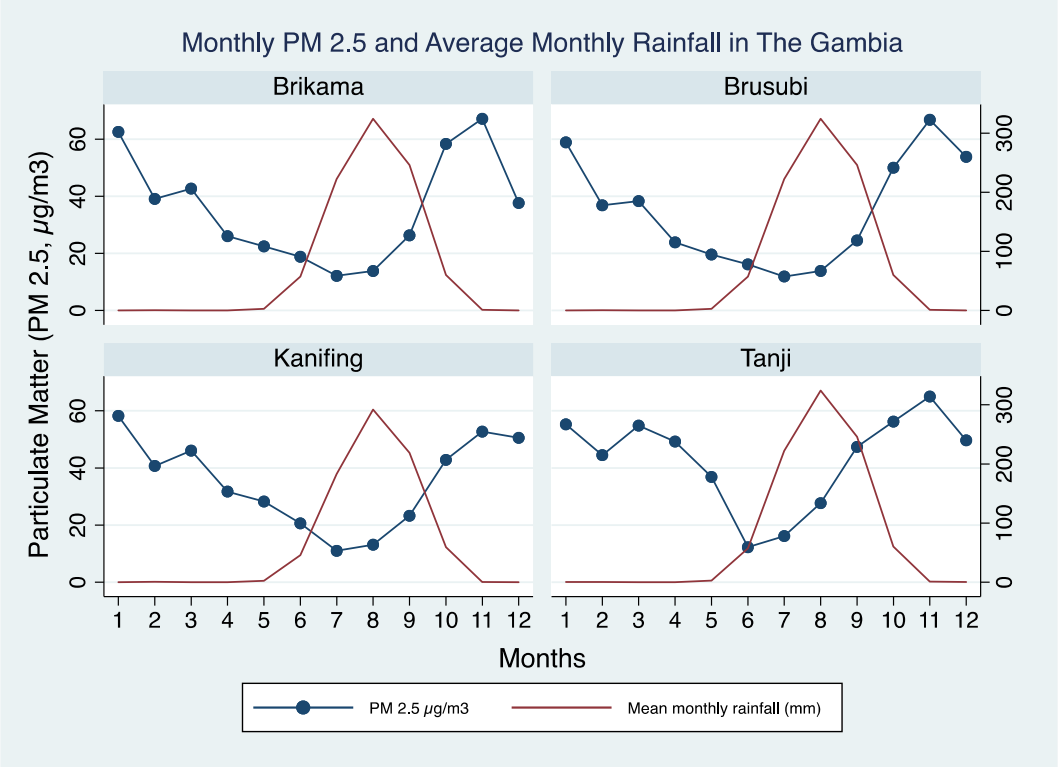

Figure 4: Monthly PM 2.5 and Rainfall in The Gambia

Correspondingly, the US Air Quality Index (US-AQI) averaged 107 (range: 96 - 117) over the 12-month period, with higher values observed in the dry season at 123 (range: 112 - 134) and lower values in the rainy season at 84 (range: 69 - 99). Of note, the dry season AQI is in the range that is unhealthy for the public and for sensitive individuals in particular who may

experience adverse health effects, including increased irritation cardiovascular and respiratory symptoms.[1]

The annual mean concentrations of PM2.5 for three out of four monitoring sites—Brikama, Brusubi, and Kanifing—were comparable. However, the coastal fishing village of Tanji exhibited significantly elevated PM2.5 levels, with an annual mean of 42.9 µg/m^3 (95% Confidence Interval: 32.4 – 53.4). Unlike the other sites, Tanji did not display notable seasonal fluctuations in PM2.5 levels. As such, Tanji is identified as a potential air pollution hotspot, attributable to the intensive fish processing activities that involve wood stove smoking, as well as contributions from sea spray aerosols.

Seasonal Differences in Air Quality at four air sensor locations in the Greater Banjul Area of The Gambia (July 2023 – June 2024)

Station	Annual Mean (Mean, 95% CI)	Dry Season (Mean, 95% CI)	Rainy Season (Mean, 95% CI)
Kanifing, Kanifing Municipality			
PM 2.5 (µg/m3)	34.9 (24.8 - 45.0)	44.0 (34.8 - 53.2)	22.2 (9.7 - 34.6)
US Air Quality Index	103 (82 - 124)	123 (101 - 144)	76 (51 - 102)
Temperature (°C)	28.4 (27.5 - 29.4)	27.4 (26.6 - 28.2)	29.8 (28.97 - 30.6)
Humidity (%)	65.8 (58.2 - 73.3)	60 (51.0 - 68.9)	73.8 (65.5 - 82.1)
Brikama, West Coast Region			
PM 2.5 (µg/m3)	35.6 (23.5 - 47.6)	42.5 (28.4 - 56.6)	25.9 (7.2 - 44.5)
US Air Quality Index	102 (78 - 126)	115 (88 - 143)	84 (45 - 123)
Temperature (°C)	27.8 (27.1 - 28.5)	27.1 (26.4 - 27.8)	28.8 (27.9 - 29.6)
Humidity (%)	66.7 (58.1 - 75.3)	58.7 (49.7 - 67.7)	78 (70.5 - 85.4)
Brusubi, West Coast Region			
PM 2.5 (µg/m3)	34.5 (22.5 - 46.6)	42.6 (27.7 - 57.4)	23.3 (7.8 - 38.7)
US Air Quality Index	102 (77 - 126)	117 (87 - 147)	80 (47 - 113)
Temperature (°C)	27.7 (26.5 - 28.8)	26.7 (25.3 - 28.1)	29 (28.3 - 29.7)
Humidity (%)	69.2 (61.7 - 76.8)	63 (54.5 - 71.7)	77.8 (69.4 - 86.2)
Tanji, West Coast Region			
PM 2.5 (µg/m3)	42.9 (32.4 – 53.4)	50.8 (43.4 - 58.2)	31.9 (12.9 -50.8)
US Air Quality Index	120 (98 - 142)	136 (121 - 151)	97 (57 - 138)
Temperature (°C)	27.9 (26.9 - 28.9)	27.1 (26.2 - 28.0)	29.0 (27.2 - 30.8)
Humidity (%)	72.3 (63.9 - 80.5)	67.2 (56.7 - 77.8)	79.2 (68.3 - 89.9)

Table 2: Air Quality Measurements from individual air sensors located in 4 towns in the Greater Banjul Area. Dry Season: November to May, Rainy Season: June to October. CI: 95% Confidence Interval

[1] World Health Organization: What are Air Quality Guidelines?

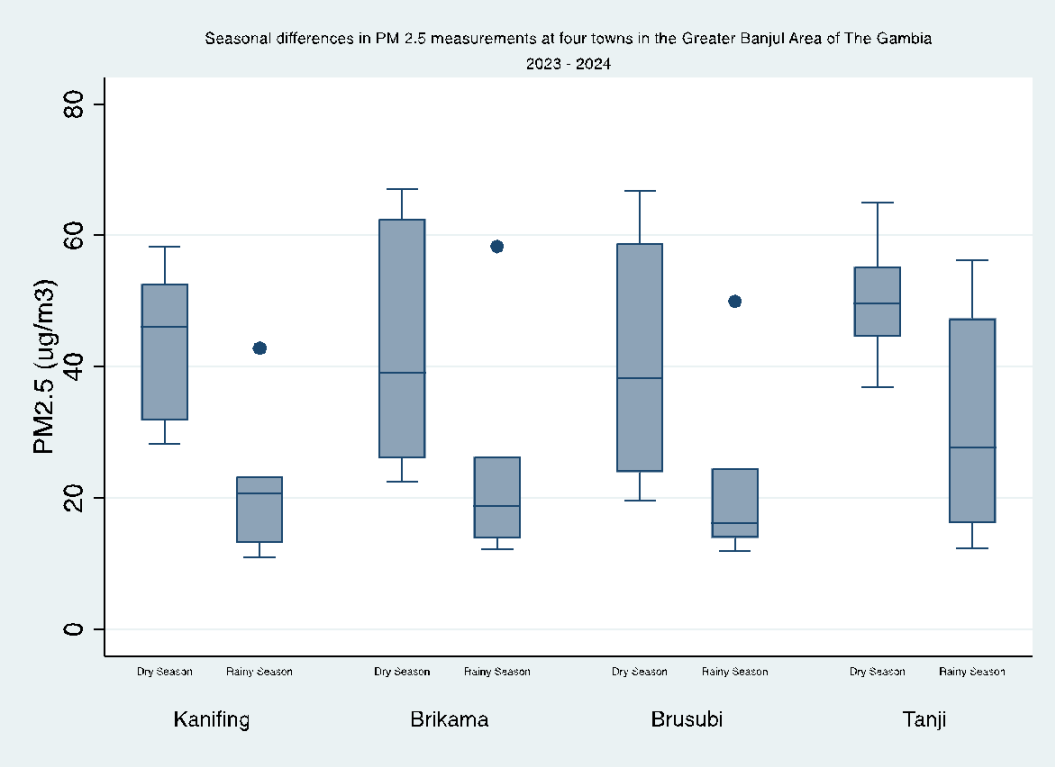

Figure 5: Seasonal Rainy Season-Dry Season Differences in PM 2.5 Measurements

Air pollution and respiratory health outcomes

To evaluate the health effects of measured PM 2.5 concentrations in the greater Banjul area, we obtained data from the Ministry of Health's District Health Information Software 2 (DHIS2), - an open-source health management information system that aids in the collection, reporting, analysis, and dissemination of health data. We compared acute asthma and pneumonia visits at four (4) health facilities near the air quality sensors- namely- Kanifing General Hospital, Brikama Major Health Center, Brusubi Health Center and Tanji Health Center for the corresponding period (July 2023 – June 2024).

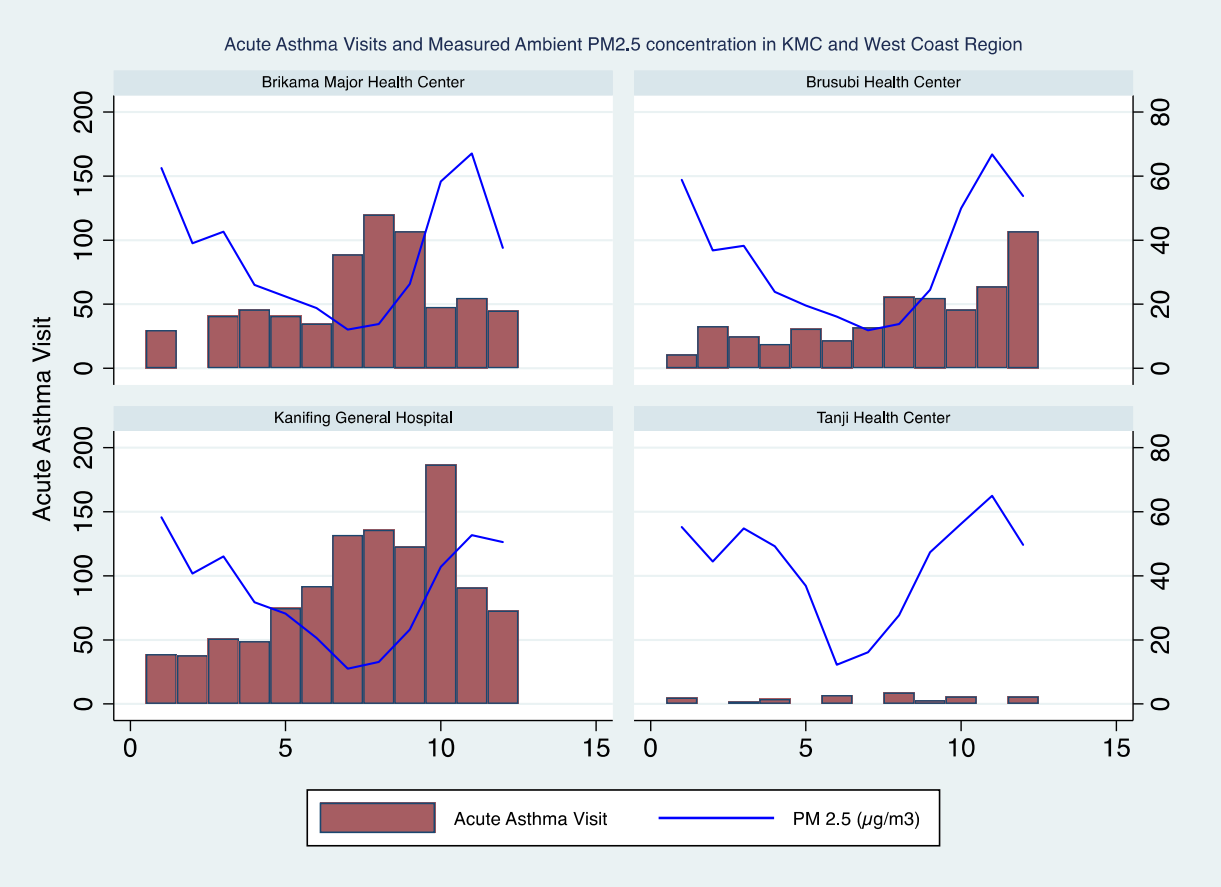

Figure 6: Acute Asthma visits and PM 2.5 measurements

Asthma Cases in the Greater Banjul Area of The Gambia (July 2023 – June 2024)

Variable	IRR	95% CI	P value
Average monthly rainfall (mm)	1.003	1.002 - 1.004	<0.0001**
Temperature (Celsius)	1.040	0.925 - 1.170	0.51
Humidity (%)	1.001	0.971 - 1.032	0.95
Particulate Matter (PM 2.5)	1.001	0.989 - 1.029	0.38
Health Facility Setting			
Tanji Health Center	Reference	-	
Brikama Major Health Center	15.93	8.584 - 29.567	<0.0001**
Kanifing General Hospital	27.92	14.108 - 55.274	<0.0001**
Brusubi Health Center	13.46	6.677 - 27.129	<0.0001**

Table 3

Number of observations = 48; Wald chi2(7) =172.70

Dispersion= mean; Prob > chi2 =0.0000

Log pseudolikelihood = -200.12959 Pseudo R2=0.1397

The data showed that while average rainfall had a statistically significant impact on asthma visits, temperature, humidity, and PM 2.5 levels did not. The substantial differences in asthma visits across different settings highlight the influence of urbanization, with urban settings showing significantly higher rates of asthma visits compared to the rural reference setting in Tanji. Further research and targeted public health interventions could help to better understand and mitigate these disparities in asthma incidence.

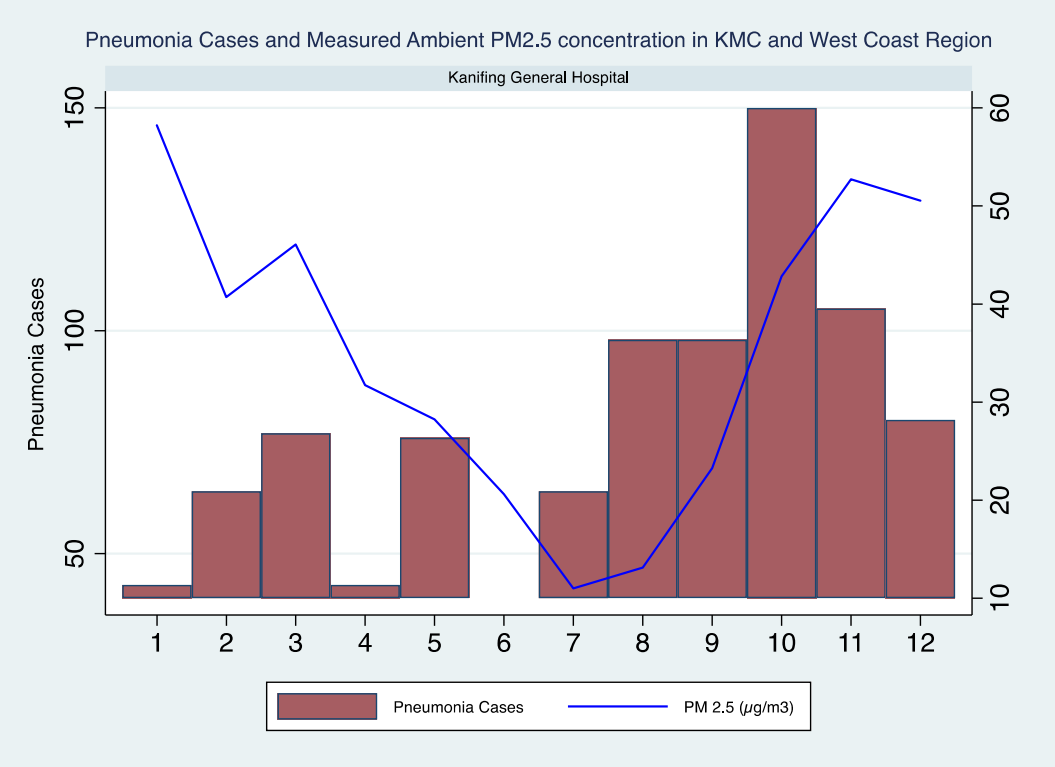

Figure 7: Pneumonia cases at Kanifing General Hospital, and PM 2.5 measurements from air sensor at Kanifing Industrial Area

Pneumonia Cases in the Greater Banjul Area of The Gambia (July 2023 – June 2024)

Variable	IRR	95% CI	P value
Average monthly rainfall (mm)	1.001	0.999 - 1.003	0.201
Temperature (Celsius)	1.000	1.002 - 1.209	0.045**
Humidity (%)	0.995	0.971 - 1.019	0.656
Particulate Matter (PM 2.5)	1.005	0.991 - 1.021	0.441
Health Facility Setting			
Tanji Health Center	Reference	-	
Brikama Major Health Center	19.52	13.209 - 28.852	<0.0001**
Kanifing General Hospital	3.15	2.084 - 4.743	<0.0001**
Brusubi Health Center	10.28	6.986 - 15.128	<0.0001**

Table 4

Temperature and the specific location of health facilities significantly impact the number of pneumonia visits in the Greater Banjul area. Rainfall, humidity, and PM2.5 levels do not show strong individual associations with pneumonia visits in this model. Notably, Brikama Major Health Center, Brusubi Health Center, and Kanifing General Hospital, all located in urban and more densely populated areas, have significantly higher rates of pneumonia visits compared to the rural Tanji Health Center, indicating that urban density substantially influences pneumonia visit rates. Referral patterns and patient healthcare-seeking behavior may also contribute to this finding. These insights have important implications for urban physical and health planning; while weather conditions and air pollution show limited direct impact, the distinction between urban and rural settings plays a critical role in the variability of pneumonia visit frequencies.

An important area that needs further study that has a direct impact on the health and the environment is the use of firewood and charcoal for domestic energy including cooking.

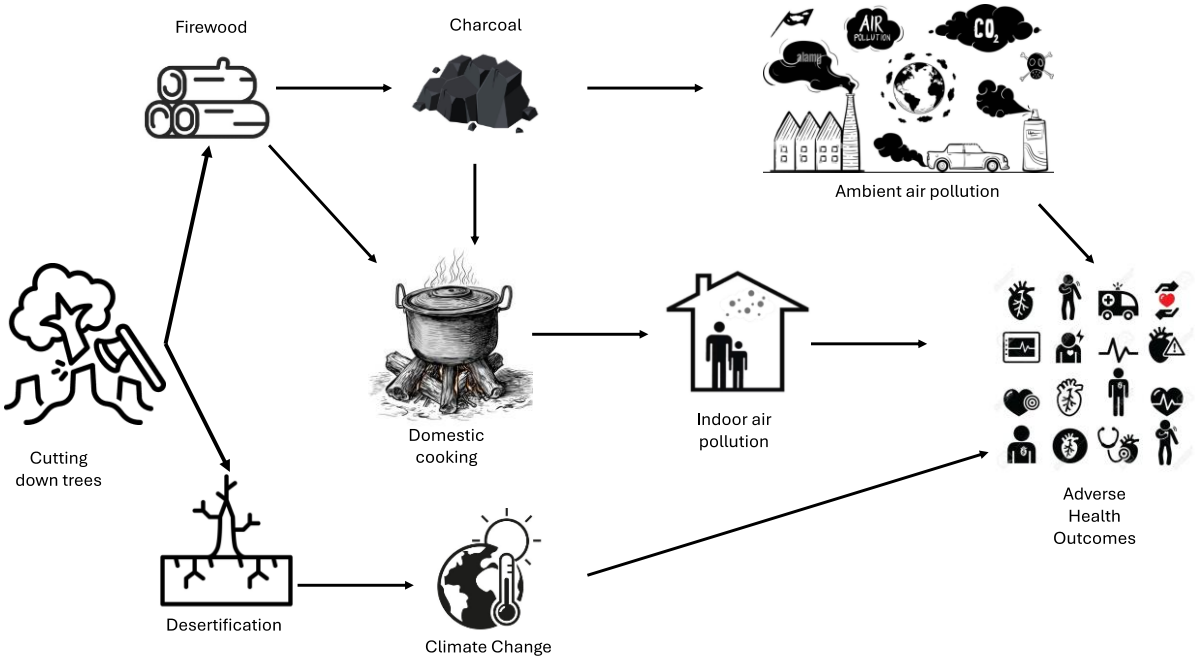

Figure 8: Trees are harvested for firewood or converted into charcoal, both of which contribute to ambient air pollution during their production. Household use of charcoal further exacerbates indoor air pollution, resulting in negative health effects. Additionally, desertification accelerates climate change, raising the likelihood of extreme weather events that can have detrimental impacts on health.

The Gambia, situated in an ecological transition zone near the Sahara Desert, faces significant environmental and health challenges exacerbated by reliance on firewood and charcoal for domestic energy. With more than 95% of households dependent on these sources[4], the implications are profound and including accelerated deforestation, contributing to desertification, and a degradation of arable land, leading to loss of biodiversity and reduced agricultural productivity (Figure 6). Burning firewood in the production of charcoal produces significant amounts of particulate matter (PM2.5), a major air pollutant linked to cancer, respiratory and cardiovascular diseases, with long-term exposure causing severe health outcomes such as chronic obstructive pulmonary disease (COPD), lung cancer, and asthma, particularly affecting women and children who spend more time near cooking stoves.[1–3,5]

Deforestation and the burning of biomass release large amounts of carbon dioxide and other greenhouse gases, contributing to global warming. Desertification further amplifies climate change effects, destabilizing local weather patterns and making the region more susceptible to extreme events like droughts and heavy rains, which can lead to increased food and water insecurity, adversely affecting health and livelihoods.

Conclusions

The Gambia is one of few countries in Africa with an extensive low-cost sensor network covering the entire country. Initial data from early air sensor installations, indicate that The Gambia experiences significant seasonal variability in PM2.5 concentrations, primarily influenced by atmospheric and meteorological conditions. During the Harmattan in the dry season, PM2.5 levels are higher due to wind-driven dust storms, while the rainy season sees a decline due to meteorological factors including rainfall and increased vegetative cover. Annual PM2.5 levels are approximately seven (7) times the WHO limit of 5 $\mu g/m^3$, peaking at nine (9) times during the dry season and reducing to five times in the rainy season. Tanji is identified as a potential pollution hotspot, primarily due to fish processing activities. Comprehensive health impact studies are urgently needed to inform national air quality policies.

Future directions

The agency is set to expand the existing network of low-cost air sensors to include a reference grade monitor and will continue to collaborate with development partners to install more sensors at strategic sites across country. The agency also aims to produce an annual comprehensive state of air quality report to inform government policy. The installation of reference-grade air quality monitoring has significantly enhanced the agency's regulatory capacity to fulfill its legal mandate. This is important because The Gambia is among many African countries that currently lack national air quality standards or emission guidelines due to insufficient measuring capacity and data. However, with the current network, the agency is well positioned to begin aligning with international standards. The Gambia has been identified by the Energy Policy Institute at the University of Chicago as a high-impact opportunity to bridge air quality data gaps, underscoring the significant potential for progress in the country.[2]

NEA will capitalize on these gains to partner with the Ministry of Health and other stakeholders to raise awareness about the importance of air pollution and how to protect themselves during periods when air quality is hazardous, especially during the Harmattan season. We will collaborate with media agencies and the University of The Gambia to promote local research capacity on air pollution. The agency has a critical need to develop local capacity to install and maintain the sensor network, ensuring the initiative's sustainability in the long term.

Finally, NEA needs support to conduct comprehensive emissions inventory assessments in The Gambia to gather baseline data on pollutant sources and quantities. This will enable the development of targeted regulations, optimize resource allocation, and monitor the efficacy of air quality measures. Accurate data from these inventories will support public awareness, international compliance, and regional cooperation while informing health impact assessments and promoting cost-effective pollution reduction strategies.

[2] Air Quality Monitoring and Data Access: Energy Policy Institute, University of Chicago

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