

Spatial and Temporal Variability of Ambient Ammonia (NH₃) in Urban and Peri-Urban Dar es Salaam, Tanzania as Measured by Low-cost Gas Sensors

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Abstract

Air pollution remains a critical global challenge, disproportionately impacting vulnerable communities in low- and middle-income countries. Weak policies, fragmented institutions, limited financial and computational resources, and lack of comprehensive monitoring infrastructure hinder effective air quality (AQ) management. Dar es Salaam city with population of about 7 million, is among the world's Megacities that is undergoing rapid urbanization with accompanying infrastructure development but with underdeveloped waste management. Monitoring of ammonia concentration gas was made at urban and peri-urban sites in Dar es Salaam city to identify its spatial and temporal variability. The monthly mean ammonia concentrations measured at two sub-urban sites (Buza Hospital and Temeke DMDP) were 34.9 and 16.6 ppm, respectively. The monthly mean ammonia concentrations at urban site (DIT, Kigamboni, Makuburi, Sinza Hospital and Mlimani city) were, 8.2, 8.85, 22.02, 16.5, and 7.2, respectively. Further, a comparison of the measured hourly data at urban and peri-urban sites showed its relative dominance at peri-urban sites during the evening hours while during the morning hours the dominance was to the urban sites. Different studies suggest that the trend of ammonia levels should be tightly affected by an increasing number of vehicles (morning traffic jams in urban areas) as well as agricultural and livestock activities (common in peri-urban areas). As such, the results of our statistical analysis point to the potentially significant role of agriculture and livestock activities in the elevation of ammonia levels in peri-urban areas of Dar es Salaam city.

1. Introduction

Dar es Salaam is currently one of the fastest-growing megacities in Sub-Saharan Africa. While infrastructure development has accelerated, municipal services particularly waste management and sanitation have struggled to keep pace with a population exceeding 7 million. Recent high-resolution monitoring has shifted the traditional understanding of urban pollution in the region. Notably, Chua et al. (2025) demonstrated that East African city centers often show lower PM_{2.5} levels than their suburbs, a phenomenon attributed to the high density of primary emission sources in residential peripheries. This is further supported by Manyele et al. (2025), whose analysis of particulate matter trends (PM_{2.5} and PM₁₀) in Dar es Salaam confirms sustained elevated concentrations that frequently breach international safety limits across the metropolitan area.

The public health implications of this air quality crisis are severe. Kamara et al. (2025) recently established a significant association between ambient particulate matter and respiratory health issues among school children in Dar es Salaam, underscoring the vulnerability of young populations in high-exposure zones. While much of this health-risk research focuses on particulates, the role of precursor gases like ammonia (NH₃) in forming secondary inorganic aerosols remains a critical data gap. Ammonia emissions in the city are increasingly linked to the infrastructure gap in waste management. Kifwe et al. (2025) highlighted the environmental burden

of major waste facilities, such as the Pugu dumpsite, noting that while leachates offer potential for a circular economy, they currently represent significant sources of uncontrolled environmental loading.

This study addresses this gap by utilizing low-cost gas sensor (LCS) technology to map NH_3 variations. By comparing the urban core with the peri-urban fringe, this research aims to determine if ammonia follows the "suburban-heavy" trend identified by Chua et al. (2025) and to identify the dominant drivers whether they stem from the city's motorization or its localized waste and agricultural management systems.

2. Methodology

The study deployed a network of low-cost gas sensors across ten strategically selected sites. Sites were categorized into Urban (high-density commercial hubs like DIT, Kigamboni, and Mlimani City) and Peri-Urban (residential areas with high biomass use and livestock, such as Buza and Temeke).

2.1 Monitoring Network and Station Locations

The geographic positioning of each station relative to Dar es Salaam's main infrastructure is presented in Figure 1. This layout captures the pollution gradients from the coastal urban center to the inland sub-urban peripheries, where waste management systems are often underdeveloped.

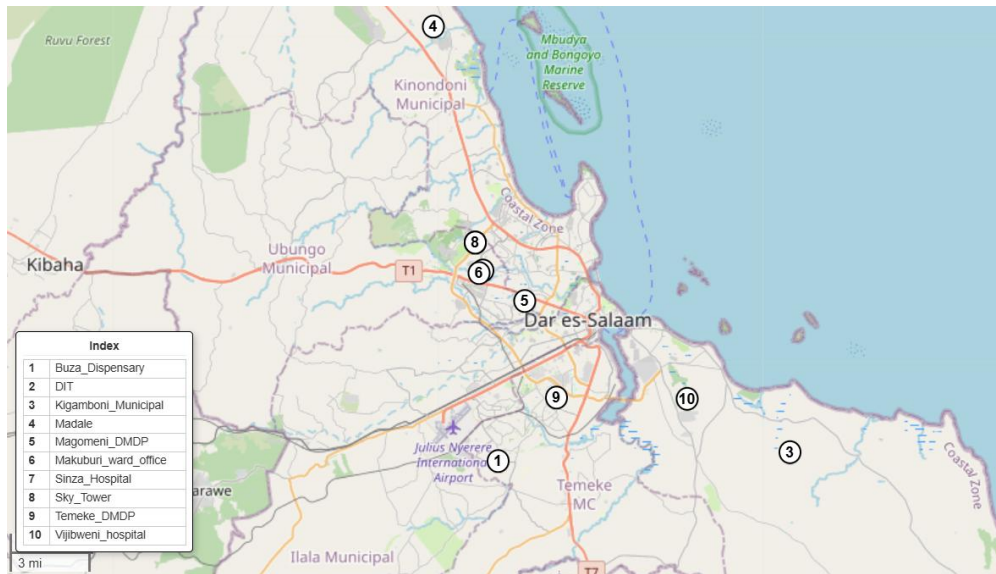


Figure 1. Geographic locations of the ten NH_3 monitoring stations in Dar es Salaam. Station indices (1–10) provide the spatial reference for subsequent data analysis.

2.2 Statistical and Temporal Analysis

Hourly data were logged to capture diurnal variations. Statistical distributions were analyzed using box-and-whisker plots to distinguish between persistent baselines and extreme emission outliers.

Temporal shifts were identified by averaging hourly concentrations over a 24-hour cycle to compare peak pollution times between urban and peri-urban environments.

3. Results and Discussion

3.1 Spatial Heterogeneity and Suburban Dominance

The results reveal a stark contrast between urban and peri-urban NH_3 levels, mirroring the suburban-heavy pollution profile identified in recent East African studies. The sub-urban site at Buza recorded a monthly mean of 34.9 ppm, the highest in the study, while the urban center at DIT remained significantly lower at 8.2 ppm.

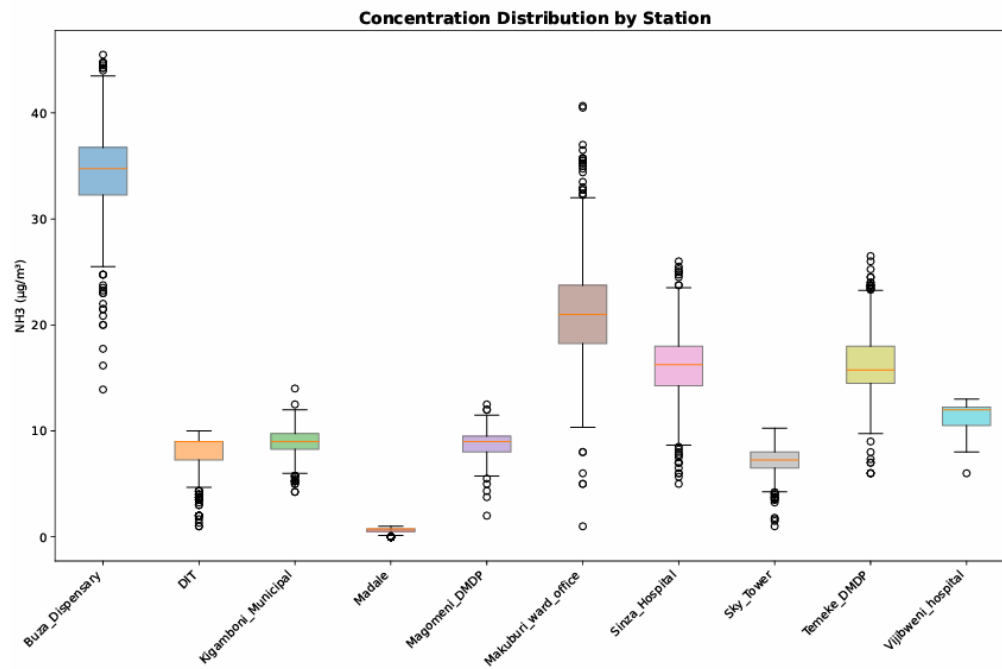


Figure 2. Statistical distribution of NH_3 by station. Median values and outliers at Buza and Makuburi (22.02 ppm) highlight the intensity of localized emission events.

This finding aligns with the research of Chua et al. (2025), suggesting that in East Africa, the highest density of primary emission sources such as domestic biomass burning and localized organic waste decomposition, is increasingly found in residential peripheries rather than the paved, commercialized urban core. The high variance at Makuburi and Buza further suggests that these areas are subject to frequent, high-intensity emission events linked to livestock waste handling and biomass combustion.

3.2 Temporal Dynamics: Morning vs. Evening Dominance

The temporal data illustrates a clear shift in dominance between monitoring zones.

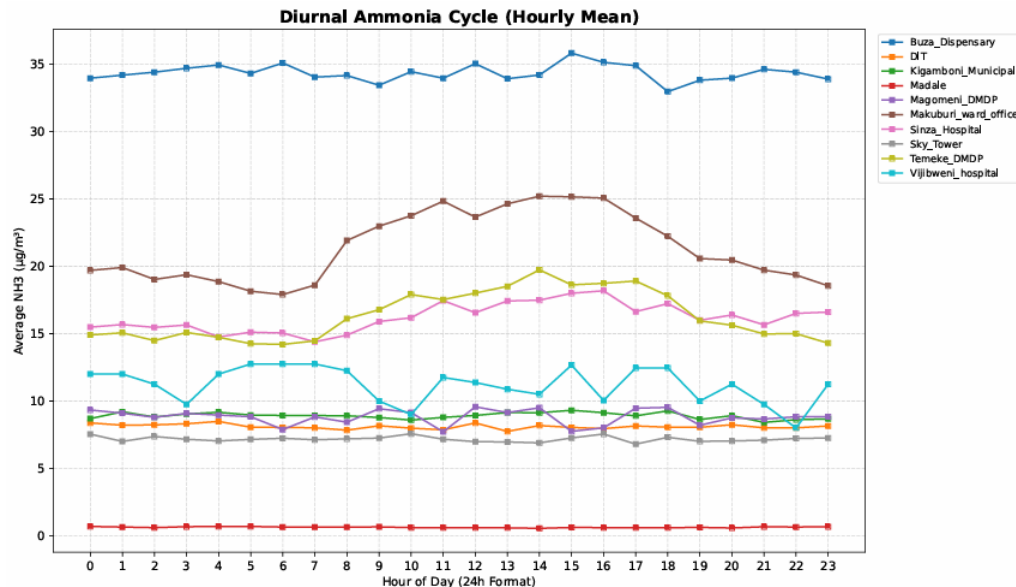


Figure 3. Hourly mean NH_3 concentrations. Urban sites show morning peaks (07:00–09:00), while peri-urban sites dominate during evening hours.

Urban sites exhibit a traditional morning peak, coinciding with vehicular traffic jams and NO_x related chemistry. However, a comparison of the measured hourly data shows the relative dominance of NH_3 at peri-urban sites during the evening hours. The Buza profile remains consistently elevated throughout the 24-hour cycle, indicating that biogenic sources like livestock and decaying organic waste provide a continuous baseline. The evening surge in these areas is likely exacerbated by domestic activities, specifically the use of charcoal for cooking, which traps pollutants near the ground as the atmospheric boundary layer collapses at sunset.

4. Conclusion

This study concludes that ammonia pollution in Dar es Salaam is governed by the city's infrastructure gap. While vehicular emissions contribute to urban morning peaks, the most significant nitrogen burden is found in peri-urban areas like Buza and Temeke. The results point to the critical role of agriculture, urban livestock, and poor waste management in elevating NH_3 levels. Effective air quality management must move beyond vehicular controls to include targeted interventions in waste infrastructure and the promotion of clean cooking energy for the city's suburban communities to protect public health.

5. References

- Chua, S. D. X., et al. (2025). East African City Centers Show Lower $\text{PM}_{2.5}$ Levels than Their Suburbs. *Environmental Science & Technology Letters*, 12(9), 1169–1176.
- Kamara, J., et al. (2025). Association between ambient particulate matter and respiratory health among school children in Dar es Salaam. *BMC Public Health*.
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