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PERSPECTIVE

Calling for synergized strategies to monitor and mitigate urban air and noise pollution in low and middle-income countries

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1. The dual challenge of urban air and noise pollution in low- and middle-income countries

Rapid urbanization in low- and middle-income countries (LMICs) has been driven by the economic opportunities a city offers and the quality of life it promises. In general, urban dwellers in LMICs have health, development, and educational advantages over their rural counterparts [1]. However, city dwellers are also at higher risk of exposure to both air and noise pollution from urban and regional sources. Growing over the last few decades, air pollution has become a major focus of urban environmental health research, activism, and policy making in many high-income countries due to the growing, and now large, body of evidence of its harmful effects on physical health, mental health, and even premature mortality [2]. These efforts have resulted in significant improvements in overall air quality in Europe and North America [3]. Although measurement data is still nascent in most LMICs, the expanding density of monitoring data is deepening our understanding of the diversity and complexity of sources of air pollution in LMICs, and driving local policy measures aimed at reducing exposure [4]. In contrast, environmental noise pollution and its health impacts remain even less studied in LMICs [5]. The lack of robust measurement and/or modeled data on source-specific noise metrics in urban LMICs hampers efforts to understand the scale of exposure and the associated disease burden. This gap creates an imbalance in addressing the broader spectrum of urban environmental health risks, leaving noise pollution as an often-unaddressed risk factor, but one that may have a significant contribution to the health and wellbeing of urban residents in LMICs. A comprehensive approach to monitoring and mitigation that places proportionate emphasis on these pollutants, especially in fast-growing cities in LMICs, is essential to improve urban environmental health outcomes in LMICs.

Air and noise pollution, particularly in urban contexts, are emitted from many shared sources, such as road traffic, railways, aircraft, construction activities, and small (informal) and large-scale industrial as well as commercial activities. Many cities also have local sources unique to their urban cultural, social, and religious context, such as household and commercial biomass use as a source of energy (air pollution) or loud music or speech emitted from speakers along the roadside for religious or commercial purposes (noise). The diversity and overlap of sources influence the spatial and temporal patterns, meaning that many urban residents may be exposed to both types of pollution year-round, especially in densely populated and mixed-land use areas, potentially enhancing health risks and vulnerabilities [2, 6].

Exposure to criteria air pollutants (e.g. $PM_{2.5}$, NO_2, O_3) are robustly associated with numerous adverse health outcomes in many high-quality longitudinal epidemiological studies conducted around the world. These include respiratory (e.g. asthma, chronic obstructive pulmonary disease), cardiometabolic (e.g. incidence and/or mortality from ischaemic heart disease, stroke, and diabetes), cognitive (e.g. vascular dementia), and birth outcomes (e.g. low birth weight), as well as all-cause premature mortality [2]. In large, longitudinal cohort studies, primarily conducted in Europe, long-term exposure to transportation noise (e.g. from road, rail, and/or aircraft sources) has also been associated with many similar cardiometabolic health outcomes and clinical markers and risk factors (e.g. blood pressure, body-mass index, hypertension), self-reported annoyance, sleep disturbances (from night-time noise exposure), and premature all-cause mortality [6]. These effects remain, even after adjustment for air pollution. There is also evidence supporting associations with impaired cognitive development amongst children (evidence from aircraft noise exposures) and mental-health impacts (e.g. depression associated with aircraft noise) [6]. Despite established independent effects on cardiometabolic health, there is still a lack of epidemiological and mechanistic (e.g. controlled laboratory studies) research and uncertainty about whether co-exposure may lead to additive—where each pollutant contributes independently to health outcomes—or if effects are multiplicative, amplifying each other's effects synergistically [7, 8].

Addressing this research gap in LMICs is critical for developing interventions and policies that protect urban populations from the potentially compounded health effects of exposure to air and noise pollution. As such, there is a need for more observational longitudinal studies investigating the impacts that short- and long-term exposures to both air and noise pollution have on the development (e.g. incidence) and worsening (e.g. exacerbation) of adverse health conditions as well as on mortality, and potentially compounded effects, over time in a diversity of urban settings and population groups. Furthermore, groups such as roadside vendors, traffic police, pedestrians, and informal and city workers (e.g. sweepers, utility workers), may be disproportionately exposed due to their proximity to major pollution sources such as road traffic, construction sites, and small-scale industrial units. Understanding the long-term health impacts on these populations is crucial for developing interventions that address their specific needs in LMICs. However, a major gap in conducting such studies, particularly with regards to environmental noise pollution, is a lack of population-scale, representative, and robust exposure data to underpin such epidemiological investigations. For example, a 2023 systematic review on environmental noise and health in LMICs only identified two population-based epidemiological studies conducted in Africa: one cross-sectional study of general self-reported wellbeing symptoms experienced by school children in Nigeria and a prospective follow-up study of aircraft noise and school children's reading comprehension in South Africa [5].

The lack of environmental noise data and health evidence in many LMIC's is not only a barrier to local environmental and public health policy making, but also means that the contribution of environmental noise on the wider global burden of disease go uncounted (e.g. in the Global Burden of Disease study), as the noise data inputs required for such global-scale estimations does not currently exist [9]. Advances in monitoring technology, such as low-cost sensors, satellites and other forms of urban imagery, offer new opportunities to develop these critical exposure datasets around the world [10].

While air pollution has rightly been a focus due to its complex chemistry and severe health impacts, the growing body of evidence on noise pollution—including its independent effects on cardiometabolic health, cognition, and mortality—calls for a more balanced approach. Historically, noise studies often focused on exposures above 55 Lden [11], likely underestimating the broader health burden. Given the multifaceted mechanisms by which noise affects health, a more proportionate approach to prioritization is now warranted, particularly in LMICs where noise pollution is under-researched and potentially at higher exposure levels

2. Advancing monitoring technologies

The monitoring of air pollution in LMICs has advanced significantly in recent years, driven by the widespread adoption of low-cost sensors, satellite data, and real-time monitoring networks. These technological innovations have enabled more accurate and granular assessments of air quality, paving the way for data-driven policies and interventions. In contrast, noise pollution monitoring has lagged behind, particularly in LMICs, where data on noise levels and other metrics is often sparse or entirely absent. This disparity is not due to a lack of available technology—e.g. validated low-cost MEMS microphone noise meters exist—but rather reflects the lack of city-wide noise monitoring networks compared to the rapid uptake of low-cost air pollution sensor networks.

The gap in noise pollution monitoring highlights broader issues in evidence generation, resource allocation, and policy priorities. Air pollution has benefited from decades of monitoring, epidemiological research, and policy evaluations, which have solidified its position as a critical public health issue. Its inclusion in global burden of disease estimates has further amplified its visibility, attracting international attention and mobilizing resources for mitigation efforts. Noise pollution, on the other hand, remains underprioritized in most LMICs, with limited data and research hindering its recognition as a significant environmental health risk. Addressing this disparity is essential to ensure a balanced approach to researching and tackling urban environmental health challenges.

There are promising opportunities to integrate noise monitoring into existing and emerging air quality monitoring frameworks in LMICs, providing a more comprehensive approach to environmental health management. Advances in sensor technology, including portable, low-cost sensors for measuring air and noise pollution, offer practical solutions for LMICs. When integrated in monitoring systems and campaigns, these sensor networks will simultaneously collect data on multiple pollutants, enabling a more thorough understanding of the spatio-temporal profiles of the pollutants, and their shared and distinct sources.

Integrating noise sensors into existing and emerging air quality networks represents a cost-effective strategy for LMIC cities to address the dual challenge of monitoring air and noise pollution. Many cities in LMICs have already invested in low-cost air quality sensors, aiming to improve their environmental monitoring capabilities with initiatives such as the BreatheLife Cities Campaign[10], Google's investments in low-cost air quality sensors across Sub-Saharan Africa through the AirQo project [12], local government efforts, NGOs, citizen groups, etc. By adding low-cost sound level meters (SLMs) to these existing or planned networks, LMIC cities can create more comprehensive monitoring systems without the need for substantial additional investment. These types of sensors (such as NoiseSentry SLMs or AudioMoth records), increasingly used globally [13], have been successfully adapted for community-led monitoring in LMICs [14], as demonstrated by Accra's spatially resolved noise maps [15] and Kigali's land-use noise assessments [16]. When setting up these devices, strategic placement (e.g. street-level deployment near traffic or industrial zones) and calibration are critical to ensure data accuracy. This approach allows for greater spatial and temporal coverage of both pollutants, providing critical data to inform holistic urban planning and public health policies, and supporting future epidemiological studies into the independent and combined health effects. While it is too early to quantify the downstream impacts of these monitoring systems, the data they generate create essential foundations for the integrated policy approaches (section 3) particularly for evaluating the effectiveness of urban planning interventions in LMIC contexts.

[10] The BreatheLife Cities Campaign campaign is led by the World Health Organization (WHO), UN Environment Programme (UNEP) and the Climate & Clean Air Coalition (CCAC), https://breathelife2030.org/.

3. Integrated urban planning and policy approaches

Urban planning plays a crucial role in managing both air and noise pollution, particularly in rapidly growing LMIC cities. Poorly planned cities, where residential areas are located near major traffic routes or industrial zones, often expose large populations to high levels of pollution. These impacts are often further exacerbated by systemic racism and classism, which disproportionately place marginalized communities in areas with higher pollution and fewer resources for mitigation [17]. Thoughtful urban design can mitigate these risks through green infrastructure—such as parks, green corridors, and buffer zones—which can reduce noise pollution while improving air quality [18, 19]. While research exists on green infrastructure and its co-benefits for air and noise pollution in high-income countries, more work is needed to determine which types are sustainable and effective in reducing exposure in diverse geographical and climatic contexts—particularly in LMICs, where suitable vegetation may differ. Moreover, not all interventions that reduce air pollution are equally effective for noise. Strategies like pedestrian zones, low-emission areas, and strategic zoning can significantly reduce exposure to air pollution [20], though more real-world evaluation research is needed on their impacts on noise, and on their overall effectiveness when implemented in LMICs.

A coordinated policy approach across pollutants and government departments—such as health, transport, environment, and urban planning—is essential for managing environmental health risks. Many sources of air and noise pollution, such as traffic, overlap, yet regulations often treat them separately. For example, vehicle emissions standards typically aim to reduce air pollutants but do not consider the noise generated by traffic. More coordinated policy efforts that address both air and noise pollution would be more effective in reducing overall exposure.

However, a major challenge in many LMICs is not just the existence of regulations, but the weak enforcement of them—particularly for noise pollution. For instance, India treats noise as part of its ambient air quality standards under the 'Noise Pollution (Regulation and Control) Rules, 2000,' notified under the 'Environment (Protection) Act, 1986.' These rules specify limits on noise in dB(A) Leq, a frequency-weighted measure of sound energy. Yet, monitoring data often lack spectral analysis, reporting only noise levels in dB(A). While spectral data would provide deeper insights, dB(A) metrics remain critical for population-level epidemiological studies, particularly in LMICs where advanced monitoring is scarce. Such data can still identify high-risk areas and inform broad mitigation strategies. Strengthening enforcement mechanisms is therefore critical, as regulations without implementation have limited impact. A more integrated and coordinated approach can help ensure that efforts to reduce pollution are comprehensive and consistent. By adopting such a holistic approach, urban planners and policymakers can develop solutions that improve overall environmental health.

Source apportionment studies, which identify specific contributors to air pollution, have been critical for designing targeted interventions and regulating industries and activities that are major emitters. However similar studies, which assess the relative contributions of different sources as they relate to noise in urban contexts have not been conducted in the same capacity. Noise source apportionment studies are also particularly needed in LMICs to understand the context specific sources of noise, which may go beyond traffic related pollution, as if often studies in European contexts. For example, a study in Accra, Ghana which used audio recording devices and analyzed the recordings with machine learning acoustic classification models found that while many areas of Accra had a high prevalence of road-traffic related sounds throughout the day and night, many different types of sounds were also present in different areas. Some of these sounds could be perceived as noise, such as human-made or music sounds occurring throughout the late hours of the night in residential areas [21].

While the focus in many high-income countries is on reducing noise from traffic related sources, in many LMICs, cultural and religious practices contribute as sources of both air and noise pollution. Festivals, religious processions, and other public celebrations often generate high levels of noise (e.g. noise from the perspective of the individuals nearby not creating or enjoying the sound) and release pollutants into the air [22, 23]. Managing these events requires culturally sensitive policies that balance pollution control with respect for local traditions. Engaging community leaders and religious authorities can help develop solutions that are both effective and acceptable to local populations. This may include scheduling events during times when pollution levels are lower or implementing noise-reduction measures that do not interfere with cultural practices.

4. Conclusion: the path forward for LMICs

Addressing both air and noise pollution is critical for reducing the environmental health burden in LMICs. As urban populations grow and pollution levels rise, integrated strategies that tackle these pollutants simultaneously are more effective and resource-efficient than isolated approaches. Technological advances in environmental monitoring, combined with innovative urban design and policy tools, enable LMICs to target both pollutants at once. Integrated monitoring is especially valuable in resource-limited settings, facilitating targeted interventions and greater public health benefits. However, policies addressing one pollutant may inadvertently worsen another; anticipating these trade-offs is essential for designing balanced, sustainable solutions. Equity must remain central to environmental health policy, as vulnerable populations—including low-income residents and informal workers—often face the highest exposures and the fewest protections. Prioritizing these groups ensures that pollution reduction benefits are distributed fairly. By adopting a holistic approach—one that accounts for co-exposures, mitigates trade-offs, and centers equity—LMICs can build healthier, more livable cities for all.

Data availability statement

No new data were created or analysed in this study.

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