

UNINTENDED INDOOR AIR QUALITY CONSEQUENCES OF COMMUNITY SECURITY MEASURES DURING COVID-19 LOCKDOWNS: TYRE-BURNING–RELATED PARTICULATE AND VOC EXPOSURE IN LAGOS, NIGERIA

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ABSTRACT

Community-level responses to COVID-19 lockdowns reshaped everyday environments, often producing unintended public health externalities. In many low- and middle-income cities, informal security practices emerged as communities sought to enforce movement restrictions and deter crime during periods of reduced policing capacity. These adaptive measures, while socially motivated, interacted with existing environmental vulnerabilities, particularly indoor air quality in densely populated residential settings. This study examines the unintended indoor air quality consequences of community security practices during COVID-19 lockdowns in Lagos, Nigeria, with a specific focus on tyre-burning used as makeshift roadblocks. From a broad perspective, the paper situates tyre-burning within the wider context of urban informal governance, energy poverty, and environmental health inequities exacerbated by pandemic restrictions. Combustion of tyres is known to emit fine particulate matter (PM_{2.5} and PM₁₀), polycyclic aromatic hydrocarbons, and volatile organic compounds (VOCs), many of which infiltrate indoor spaces in high-density housing. Narrowing the focus, the study synthesizes observational evidence, indoor exposure pathways, and household-level vulnerability factors relevant to Lagos communities during lockdown periods. Particular attention is given to ventilation limitations, building envelope permeability, and prolonged indoor occupancy, which together amplified exposure risks. The analysis highlights how episodic outdoor burning events translated into sustained indoor pollutant accumulation, disproportionately affecting children, older adults, and individuals with pre-existing respiratory conditions. The findings underscore a critical policy gap at the intersection of public health emergency response, community security, and environmental regulation. While lockdowns aimed to reduce viral transmission, unregulated security practices introduced competing respiratory health risks. The study argues for integrated emergency planning that anticipates secondary environmental exposures and promotes non-combustive community safety strategies in rapidly urbanising contexts globally relevant.

Keywords:

Indoor air quality; COVID-19 lockdowns; tyre burning; particulate matter; volatile organic compounds; Lagos Nigeria

1. INTRODUCTION

1.1 COVID-19 Lockdowns and Community-Level Security Responses

Public health lockdowns introduced during pandemic response periods exposed structural gaps in urban governance, particularly in low- and middle-income cities. Restrictions on movement, reduced economic activity, and limited enforcement capacity strained formal security institutions, creating conditions in which state presence became uneven across neighbourhoods [1]. In densely populated urban areas, policing resources were often redirected toward major transport corridors and commercial zones, leaving residential communities to manage security concerns independently.

In response, informal and community-driven security measures emerged as adaptive strategies. Local groups organised night patrols, erected makeshift roadblocks, and implemented access controls to regulate movement within neighbourhoods [4]. These actions were motivated by a combination of crime prevention, compliance with movement restrictions, and collective protection during periods of uncertainty. Such measures frequently relied on readily available materials and locally accepted practices rather than formal infrastructure.

The decentralisation of security responsibilities altered everyday urban practices. Community-level interventions operated outside established regulatory frameworks, allowing rapid deployment but limiting oversight [2]. In many cases, enforcement methods prioritised visibility and deterrence, reinforcing social order through symbolic

displays rather than institutional authority. While these approaches filled immediate security gaps, they also introduced new environmental interactions that were not explicitly considered during implementation.

Public health emergencies therefore reshaped urban environments not only through formal policy but also through informal governance mechanisms [6]. Community security responses interacted with existing infrastructural limitations, dense housing patterns, and environmental vulnerabilities. The material choices and enforcement strategies adopted at neighbourhood levels had consequences that extended beyond security outcomes alone. Understanding these responses as environmental as well as social phenomena provides a critical transition toward examining how emergency-driven practices reconfigured exposure conditions within urban settings [8].

1.2 Indoor Air Quality as an Unintended Pandemic Externality

Pandemic risk management was largely framed through an infection-centric lens, with primary emphasis placed on reducing viral transmission through distancing, movement restrictions, and hygiene practices [3]. While these measures addressed immediate public health priorities, they also altered exposure landscapes in ways that received comparatively little attention. As lockdowns prolonged, indoor environments became the dominant setting for daily life, shifting risk profiles from predominantly outdoor and occupational exposures toward sustained indoor contact with environmental pollutants.

Indoor air quality risks intensified during these periods due to multiple converging factors. Prolonged indoor occupancy increased cumulative exposure durations, while reduced mobility limited opportunities for environmental recovery through dispersion and dilution [7]. Ventilation practices were frequently constrained by security concerns, noise, and thermal comfort, particularly in dense urban neighbourhoods. These conditions created indoor environments where pollutants could accumulate over time.

Unintended externalities emerged as communities adopted practices that altered local environmental conditions. Combustion-based security measures, such as the burning of materials to create physical or symbolic barriers, generated airborne pollutants that infiltrated nearby indoor spaces [5]. Unlike outdoor pollution episodes that are transient or regulated, these emissions occurred close to residential buildings and during periods of continuous indoor presence.

This shift highlights the need to move from infection-centric risk assessments toward exposure-centric frameworks that capture broader environmental health consequences [1]. Indoor air quality became an implicit determinant of health during lockdowns, shaped by behavioural adaptations and community-level decisions. Narrowing the analytical focus toward combustion-based practices allows for a more precise examination of how informal security measures translated public health emergencies into unintended indoor exposure pathways [8].

2. COMMUNITY SECURITY PRACTICES AND ENVIRONMENTAL EXPOSURE PATHWAYS

2.1 Informal Roadblocks and Tyre Burning as Security Mechanisms

During periods of restricted mobility and limited formal enforcement, communities adopted informal roadblocks as practical tools for regulating access and asserting local control. Tyre burning emerged as a preferred mechanism due to its high visibility, rapid deployment, and symbolic deterrent effect [6]. Burning tyres produce dense black smoke and strong odours that signal enforcement presence, discourage unauthorised entry, and communicate collective vigilance to residents and passers-by alike. These attributes made tyre burning an accessible option for communities operating with minimal resources.

The rationale for tyre burning also reflects contextual constraints. Tyres are readily available waste materials in many urban areas, requiring no specialised equipment to ignite [9]. Their use aligns with established protest and enforcement practices in several cities, where combustion serves both functional and communicative roles. In security contexts, the smoke plume functions as a boundary marker, delineating controlled space while reinforcing social compliance [12]. Such practices were often perceived as temporary and necessary responses to exceptional circumstances.

Spatial considerations played a critical role in shaping exposure outcomes. Informal roadblocks were typically established at neighbourhood entrances, junctions, or narrow access roads, locations that are frequently adjacent to residential dwellings [7]. In high-density urban settings, these sites are often within a few metres of homes, shops, and shared courtyards. The proximity of burning activities to living spaces increased the likelihood that emissions would directly affect indoor environments.

These roadblocks were not isolated or sporadic. In many communities, tyre burning occurred repeatedly, particularly during evening hours when security concerns intensified [14]. Recurrent combustion events compounded local pollution levels and extended exposure duration. Although the primary intent of these practices was security enforcement, their environmental implications were rarely considered. This disconnect highlights a

critical transition point: measures designed to protect community safety simultaneously generated pollutants capable of undermining indoor environmental health [10].

2.2 Pollutant Emissions from Tyre Combustion in Urban Settings

The combustion of tyres releases a complex mixture of airborne pollutants with well-documented toxicity profiles. Incomplete burning produces high concentrations of particulate matter, including PM_{2.5} and PM₁₀, alongside ultrafine particles capable of deep respiratory penetration [8]. These particles are composed of carbonaceous material, metal residues, and organic compounds that contribute to both acute and chronic health risks.

In addition to particulate matter, tyre combustion emits a range of volatile organic compounds and polycyclic aromatic hydrocarbons [11]. VOCs released during burning include aromatic hydrocarbons and oxygenated compounds that readily disperse and infiltrate surrounding spaces. PAHs, many of which are known carcinogens, adhere to particulate surfaces and persist in the environment. Soot generated from tyre fires further exacerbates pollution by absorbing and transporting toxic compounds.

Dispersion dynamics in dense urban neighbourhoods amplify the impact of these emissions. Narrow streets, closely spaced buildings, and limited airflow restrict pollutant dilution [6]. Smoke plumes may become trapped within street canyons, increasing local concentrations and prolonging exposure. Under calm atmospheric conditions, pollutants remain suspended near ground level, facilitating entry into nearby buildings through windows, doors, and ventilation openings [13].

Temporal factors further influence exposure patterns. Tyre burning often occurs during nighttime or early morning hours when atmospheric mixing is reduced [9]. These conditions favour pollutant accumulation and limit dispersion, resulting in elevated concentrations persisting into periods of peak indoor occupancy. The episodic yet intense nature of these emissions creates short-term peaks that translate into longer-term indoor contamination through infiltration and surface deposition.

Understanding the emission profile and dispersion behaviour of tyre combustion provides the scientific basis for examining indoor air quality impacts. The characteristics of particulate matter, VOCs, and soot released during burning establish clear pathways through which outdoor security practices become indoor environmental hazards [14]. This linkage sets the foundation for analysing indoor infiltration mechanisms and associated health implications in subsequent sections.

Figure 1: Conceptual Framework Linking Community Security Practices to Outdoor Emissions and Indoor Air Quality Impacts

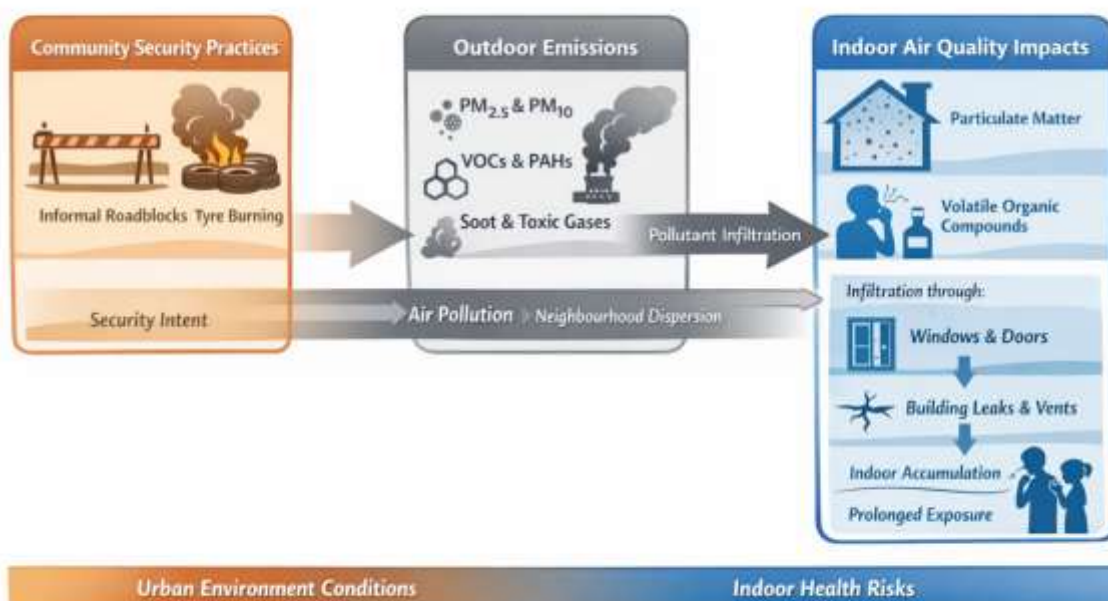


Figure 1: Conceptual framework linking community security practices to outdoor emissions and indoor air quality impacts

3. HEALTH EFFECTS OF TYRE-BURNING–RELATED AIR POLLUTANTS

3.1 Volatile Organic Compounds and Toxicological Concerns

Tyre combustion is a significant source of volatile organic compounds with well-established toxicological relevance. Among the most prominent compounds released are benzene, toluene, styrene, and related aromatic hydrocarbons, which are generated through incomplete combustion of synthetic rubber and petroleum-based additives [12]. These compounds readily volatilise at ambient temperatures, facilitating their dispersion into surrounding environments and subsequent infiltration into indoor spaces.

Acute exposure to tyre-derived VOCs has been associated with mucosal irritation, headaches, dizziness, and nausea, symptoms commonly reported during or shortly after combustion events [15]. These effects arise from rapid inhalation of high-concentration plumes, particularly in enclosed settings where ventilation is limited. The olfactory detectability of these compounds often precedes more subtle neurological responses, masking the onset of toxic effects.

Chronic exposure pathways are of particular concern in lockdown contexts. Benzene, for example, is a known hematotoxic and carcinogenic compound, with no clearly defined safe exposure threshold [18]. Repeated low-level exposure to benzene and related VOCs has been linked to bone marrow suppression, immune dysfunction, and long-term cancer risk. Styrene and toluene have been associated with neurobehavioral effects, including impaired cognitive function and chronic fatigue [14].

Indoor environments exacerbate these risks by prolonging exposure duration. VOCs infiltrating buildings may persist due to adsorption onto interior surfaces and subsequent re-emission [19]. In households subjected to repeated outdoor burning events, cumulative exposure becomes likely even in the absence of continuous combustion. The combination of episodic high-intensity exposure and sustained low-level indoor presence creates complex toxicological profiles that challenge conventional risk assessment frameworks. Recognising the specific VOCs associated with tyre combustion is therefore essential for understanding the broader health implications of community-level security practices [20].

3.2 Indoor Particulate Matter Exposure and Respiratory Outcomes

Particulate matter generated by tyre burning constitutes a parallel and often synergistic health hazard. Fine particles, particularly PM_{2.5}, are produced in substantial quantities during incomplete combustion and possess aerodynamic properties that facilitate deep lung penetration [13]. These particles readily infiltrate indoor environments through openings in the building envelope, especially in densely built neighbourhoods with close proximity to combustion sites.

Once indoors, fine particulate matter exhibits high persistence. PM_{2.5} remains suspended for extended periods under low ventilation conditions, while larger PM₁₀ particles settle onto surfaces but are easily resuspended through routine household activity [16]. This persistence transforms short-lived outdoor pollution episodes into prolonged indoor exposure events. Indoor deposition also increases the likelihood of dermal contact and ingestion, particularly among young children.

Respiratory outcomes associated with particulate exposure are well documented. Inhalation of fine particles triggers inflammatory responses in the airways, exacerbates asthma symptoms, and contributes to reduced lung function [12]. Cardiopulmonary effects include increased heart rate variability, endothelial dysfunction, and elevated risk of acute cardiovascular events [17]. During lockdown periods, these effects are intensified by prolonged indoor confinement and reduced opportunities for exposure avoidance.

The toxicity of particulate matter from tyre combustion is amplified by its chemical composition. Particles often carry adsorbed PAHs, metals, and organic toxins that enhance oxidative stress and inflammatory potential [20]. Indoor exposure to such complex particle mixtures poses particular risks in residential settings lacking filtration or mechanical ventilation. The combined physical and chemical burden of tyre-derived particulate matter underscores its role as a critical determinant of respiratory and systemic health outcomes [14].

3.3 Susceptible Populations Under Lockdown Conditions

Health risks associated with tyre-burning–related indoor pollution are not evenly distributed across populations. Children are especially susceptible due to higher respiratory rates, developing immune systems, and greater time spent indoors during lockdowns [15]. Exposure during early life stages has been linked to impaired lung development and increased lifetime risk of respiratory disease. Indoor particulate resuspension further elevates exposure for children who engage in floor-level activities.

Older adults represent another high-risk group. Age-related declines in respiratory and cardiovascular resilience reduce the body's capacity to compensate for pollutant-induced stress [18]. Prevalent chronic conditions such as hypertension, chronic obstructive pulmonary disease, and ischemic heart disease heighten vulnerability to both

particulate and VOC exposure. For older individuals confined indoors during lockdowns, repeated exposure episodes may precipitate acute health events.

Individuals with asthma and other chronic respiratory conditions face compounded risks. Fine particulate matter and VOCs act as potent triggers for bronchoconstriction and airway inflammation [12]. Lockdown-related disruptions to healthcare access may further limit management options, intensifying health consequences. Socioeconomic constraints can also restrict the ability to mitigate exposure through relocation or building modifications.

These susceptibility patterns are shaped by broader structural and environmental conditions. High-density housing, limited ventilation, and proximity to combustion sites intersect with physiological vulnerability to produce disproportionate health burdens [19]. Recognising these at-risk groups provides a necessary transition toward examining how such vulnerabilities manifest within the specific urban context of Lagos, where social, spatial, and environmental factors converge [20].

4. URBAN LAGOS CONTEXT: BUILT ENVIRONMENT AND LOCKDOWN DYNAMICS

4.1 Residential Density, Housing Typologies, and Ventilation Practices

Residential environments in Lagos are shaped by high population density and heterogeneous housing typologies that significantly influence indoor air quality dynamics. Common forms include compound housing, multi-tenant tenement buildings, and extensive informal settlements, each characterised by shared spaces, limited setbacks, and close proximity between structures [18]. These spatial arrangements reduce airflow around buildings and increase the likelihood that outdoor pollutants generated nearby will directly enter living spaces.

Compound housing typically involves multiple households clustered around a shared courtyard, with rooms opening directly onto common circulation areas. While this configuration supports social interaction, it also facilitates the spread of airborne pollutants across dwellings [21]. Tenement buildings, often constructed to maximise rental occupancy, feature narrow corridors, limited window access, and internal rooms that depend on indirect ventilation. Informal settlements exhibit similar constraints, frequently compounded by ad hoc extensions and non-standard building materials [24].

Reliance on natural ventilation is a defining feature across these housing types. Windows, doors, and improvised openings serve as the primary means of air exchange in the absence of mechanical systems [19]. However, the effectiveness of natural ventilation is highly variable. In dense neighbourhoods, surrounding buildings obstruct wind flow, while perimeter fencing and security measures further restrict air movement. Ventilation openings are often closed for privacy, security, or noise reduction, particularly during nighttime hours.

These ventilation limitations create indoor environments that are highly sensitive to external pollution sources. Pollutants released near residential structures can readily infiltrate and accumulate indoors, especially when air exchange rates are low [25]. The structural characteristics of Lagos housing therefore establish baseline vulnerabilities that magnify the indoor impact of outdoor combustion activities. Understanding these housing and ventilation conditions provides essential context for examining how lockdown measures translated community-level actions into sustained indoor exposure risks [20].

4.2 COVID-19 Lockdowns and Prolonged Indoor Occupancy

Lockdown measures introduced to limit disease transmission dramatically altered patterns of daily life in Lagos, intensifying indoor occupancy across residential settings. Stay-at-home directives reduced mobility, curtailed informal economic activities, and confined large segments of the population to their homes for extended periods [22]. These restrictions transformed indoor spaces from transient environments into primary locations for work, education, and social interaction.

Prolonged indoor occupancy amplified exposure to indoor air pollutants by increasing the duration of inhalation and limiting opportunities for avoidance [18]. In households located near informal roadblocks or security points, emissions from combustion-based practices coincided with continuous indoor presence. Unlike pre-lockdown conditions, residents were unable to temporarily relocate or reduce exposure by spending time outdoors. This shift elevated cumulative exposure even when pollutant concentrations fluctuated.

Behavioural adaptations further influenced exposure patterns. Concerns about safety and compliance with movement restrictions often led households to keep windows and doors closed, particularly during periods of heightened security enforcement [24]. Reduced ventilation compounded pollutant retention, allowing infiltrated emissions to persist indoors. In multi-occupant dwellings, shared air volumes increased exposure for all residents, while routine activities such as cooking and cleaning contributed to pollutant resuspension.

The interaction between confinement and exposure was not uniform across the city. Lower-income households, often residing in smaller and more crowded units, experienced higher exposure intensity due to limited space and

reduced ventilation options [19]. Children and older adults, who spent the greatest proportion of time indoors, faced disproportionate risk. These dynamics illustrate how behavioural constraints imposed by lockdowns interacted with environmental conditions to amplify exposure pathways.

By linking prolonged indoor occupancy with external emission sources, lockdown measures inadvertently intensified indoor air quality risks [25]. This convergence of behavioural restriction and environmental exposure provides a critical transition toward examining the governance structures that allowed such risks to persist without mitigation.

4.3 Governance Gaps and Absence of Environmental Oversight

The indoor air quality impacts of community security practices during lockdowns unfolded within a governance context marked by regulatory gaps and limited environmental oversight. Informal security measures, including tyre burning and makeshift roadblocks, operated largely outside formal regulatory frameworks [21]. While such practices were tolerated or tacitly accepted as emergency responses, they were rarely subjected to environmental assessment or enforcement.

Environmental regulations in Lagos primarily address industrial emissions and outdoor air pollution, offering limited mechanisms for controlling small-scale, community-level combustion sources [23]. Informal activities fall beyond the reach of routine monitoring systems, creating enforcement blind spots. During lockdowns, regulatory attention was further diverted toward public health enforcement, reducing capacity to address secondary environmental risks.

Institutional fragmentation compounded these challenges. Responsibilities for security, public health, and environmental protection are distributed across multiple agencies with limited coordination [18]. Community-driven actions therefore emerged in a regulatory vacuum, where accountability for environmental consequences was unclear. Residents affected by pollution had few avenues for redress, particularly during periods of restricted movement.

The absence of environmental oversight had tangible health implications. Without guidance or intervention, combustion-based security practices persisted despite their proximity to residential dwellings [25]. Public awareness of indoor air quality risks remained low, and protective measures such as temporary relocation or ventilation guidance were largely absent. This governance gap allowed short-term security objectives to override longer-term environmental health considerations.

Addressing these vulnerabilities requires recognising informal security practices as components of the urban environmental system rather than isolated social actions [22]. Examining governance failures provides a necessary foundation for developing integrated policy responses that balance community safety with environmental protection, setting the stage for subsequent discussion of exposure mitigation and public health intervention.

Table 1: Common Community Security Measures During Lockdowns and Associated Air Pollutant Emissions

Community Security Measure	Primary Purpose	Material or Activity Involved	Key Air Pollutants Emitted	Indoor Air Quality Implication
Tyre burning at roadblocks	High-visibility deterrence and access control	Combustion of used vehicle tyres	PM _{2.5} , PM ₁₀ , VOCs, PAHs, soot, toxic gases	Rapid infiltration and prolonged indoor accumulation
Burning of mixed waste	Symbolic enforcement and obstruction	Plastic, rubber, organic waste	PM, VOCs, dioxins, furans	Elevated toxic indoor exposure
Makeshift barricades with fire	Physical and psychological deterrence	Wood, rubber, debris combustion	PM _{2.5} , CO, VOCs	Acute indoor pollution episodes
Night-time combustion practices	Enhanced night security perception	Sustained or repeated burning	Fine particulates, PAHs	Reduced dispersion and increased indoor retention
Re-ignition of fire barriers	Continuous enforcement presence	Repeated combustion events	Cumulative PM and VOC emissions	Transition from episodic to chronic exposure
Security fires near residential buildings	Control of neighbourhood access points	Proximity-based combustion	PM _{2.5} , ultrafine particles	Disproportionate indoor exposure in adjacent homes

Community Security Measure	Primary Purpose	Material or Activity Involved	Key Air Pollutants Emitted	Indoor Air Quality Implication
Closure of windows during enforcement	Personal safety and compliance	Reduced ventilation behaviour	Pollutant trapping	Increased exposure duration indoors
Informal patrols with combustion cues	Community-led enforcement signalling	Smoke-based visibility markers	Mixed combustion pollutants	Household-level indoor contamination

5. INDOOR INFILTRATION AND ACCUMULATION MECHANISMS

5.1 Outdoor-to-Indoor Transport of Tyre-Burning Emissions

The transport of tyre-burning emissions from outdoor sources into indoor environments is governed by multiple physical pathways that are particularly pronounced in dense urban residential settings. Building envelope leakage represents a primary mechanism through which particulate matter and volatile organic compounds penetrate indoor spaces [23]. Cracks in walls, gaps around windows and doors, and porous construction materials allow polluted outdoor air to enter dwellings with minimal resistance, especially during active combustion events.

Windows and doors serve as direct infiltration pathways, particularly in naturally ventilated buildings where openings remain partially or fully open for thermal comfort [27]. In Lagos neighbourhoods, residential structures are often located within close proximity to informal roadblocks, enabling smoke plumes to enter indoor spaces almost immediately following ignition. Even when openings are closed, infiltration occurs through imperfect seals and pressure differentials created by wind and temperature gradients [25].

Ventilation pathways intended to improve indoor air quality can paradoxically facilitate pollutant entry. Passive ventilation openings, vents, and improvised airflow channels may draw contaminated air indoors during periods of outdoor pollution [29]. In multi-unit dwellings, shared corridors and stairwells act as conduits, allowing emissions to migrate across multiple households. These interconnected spaces effectively distribute pollutants beyond their point of origin.

The efficiency of outdoor-to-indoor transport is further enhanced during episodic burning events. High emission intensity combined with short distances between sources and residences produces elevated indoor concentrations within minutes [24]. Unlike diffuse urban pollution, tyre-burning emissions are spatially concentrated and temporally intense, overwhelming natural dilution mechanisms. This rapid transport establishes the initial conditions for indoor accumulation, highlighting how community-level combustion practices directly translate into residential exposure risks [30].

5.2 Pollutant Retention During Episodic Burning Events

Once tyre-burning emissions enter indoor environments, retention processes determine the duration and intensity of exposure. Episodic burning events produce short-term concentration spikes that may exceed background levels by several orders of magnitude [26]. While these peaks are transient outdoors, indoor environments transform them into prolonged exposure episodes due to limited ventilation and surface interactions.

Short-term spikes contribute disproportionately to cumulative indoor pollutant loading. Fine particulate matter remains suspended in indoor air for extended periods, particularly under low air exchange conditions [28]. Larger particles deposit on surfaces but are easily resuspended through routine movement, cleaning, or airflow disturbances. These processes extend exposure beyond the combustion period itself.

Surface adsorption plays a critical role in pollutant retention. VOCs and semi-volatile compounds adhere to walls, ceilings, furniture, and textiles, creating secondary reservoirs within the indoor environment [23]. Over time, these compounds may re-emit back into the air, sustaining indoor concentrations even after outdoor levels have declined. This sorption-desorption cycle complicates exposure assessment by decoupling indoor air quality from real-time outdoor conditions.

Cumulative indoor loading becomes particularly significant when episodic events recur. Repeated tyre-burning episodes prevent complete pollutant clearance between events, leading to progressively elevated baseline concentrations [30]. This layered exposure pattern shifts health risk profiles from acute irritation toward chronic exposure scenarios. Understanding retention dynamics is therefore essential for linking episodic outdoor combustion to sustained indoor environmental degradation [25].

5.3 Interaction of Climate, Ventilation, and Exposure Duration

Climatic conditions exert a strong influence on the accumulation and persistence of indoor pollutants. In tropical urban environments, high temperatures and humidity affect both emission behaviour and ventilation effectiveness [27]. Elevated temperatures increase the volatility of organic compounds, enhancing their persistence in indoor air following infiltration. Humidity influences particle hygroscopicity and surface adsorption processes, altering pollutant behaviour indoors.

Ventilation practices interact closely with these climatic factors. During periods of stagnant air or low wind speeds, outdoor dispersion is reduced, increasing the likelihood that pollutants will infiltrate nearby buildings [24]. Indoors, occupants may limit ventilation to manage heat, noise, or security concerns, particularly at night when tyre-burning events are more common. Reduced air exchange prolongs pollutant residence time and intensifies exposure.

Exposure duration emerges as a critical determinant of health risk under these conditions. Lockdown-related confinement increased the amount of time individuals spent indoors, transforming episodic pollution events into extended exposure experiences [29]. Even moderate indoor concentrations can produce significant cumulative doses when exposure is continuous. Children, older adults, and individuals with respiratory conditions are especially affected by prolonged indoor presence.

The interaction between climate, ventilation, and behavioural constraints creates a feedback loop that favours indoor pollutant accumulation. This convergence bridges physical transport processes with measurable exposure outcomes, providing a necessary transition toward empirical assessment of indoor pollutant levels and associated health effects in Lagos communities [30].

Figure 2: Indoor Accumulation Dynamics of Particulate Matter and Volatile Organic Compounds Following Outdoor Tyre-Burning

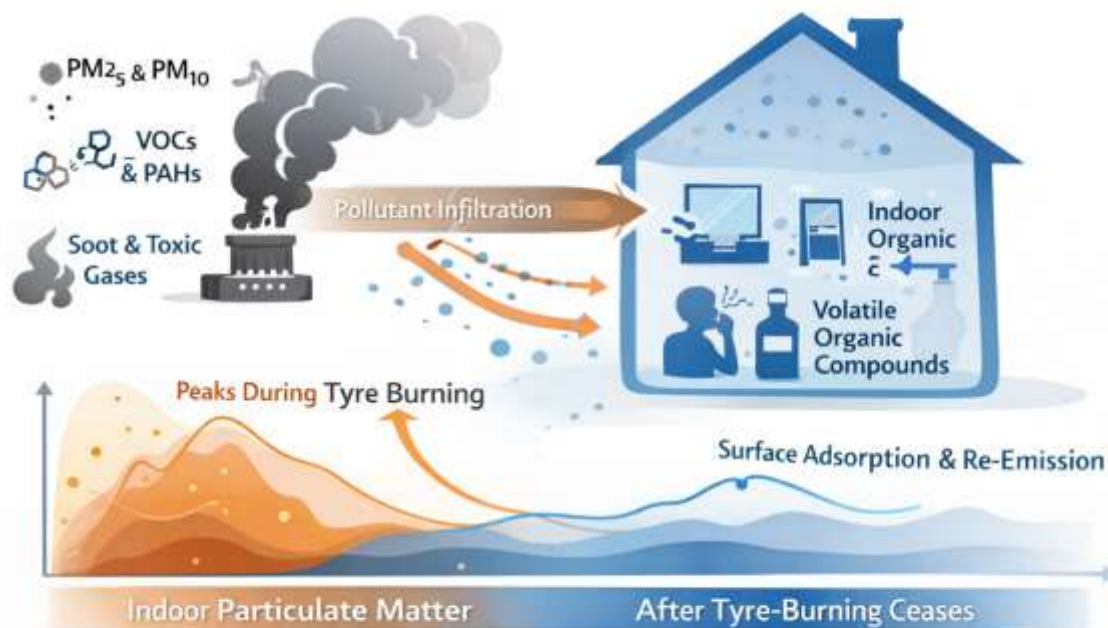


Figure 2: Indoor accumulation dynamics of particulate matter and volatile organic compounds following outdoor tyre-burning events

6. EVIDENCE SYNTHESIS: OBSERVATIONS, MEASUREMENTS, AND RISK CHARACTERISATION

6.1 Insights from Urban Air Quality and Indoor Exposure Studies

Urban air quality research conducted in large, densely populated cities provides critical context for interpreting indoor exposure conditions during lockdown periods. Studies across megacities have consistently demonstrated strong coupling between outdoor pollution episodes and indoor air quality, particularly where buildings rely on natural ventilation and exhibit high envelope permeability [28]. In such settings, indoor-outdoor concentration

ratios for fine particulate matter frequently approach unity, indicating limited attenuation of external pollution sources.

Evidence from Lagos and comparable urban environments suggests that episodic combustion events can produce indoor concentrations that rival, and at times exceed, ambient outdoor levels [31]. Measurements and proxy indicators from traffic corridors, informal industrial zones, and neighbourhood-scale burning activities show rapid transmission of pollutants into nearby residences. Indoor–outdoor ratios for PM_{2.5} have been observed to increase during nighttime hours, when reduced atmospheric mixing coincides with constrained ventilation practices [29]. Volatile organic compounds display similar coupling behaviour, though with greater temporal persistence indoors. VOCs associated with combustion infiltrate buildings quickly and may remain detectable long after outdoor concentrations decline due to surface adsorption and re-emission processes [34]. As a result, indoor–outdoor ratios for certain compounds increase over time, reflecting cumulative indoor loading rather than immediate outdoor conditions.

Comparative studies from other megacities in low- and middle-income regions reinforce these patterns. High-density housing, close proximity to emission sources, and limited mechanical ventilation produce indoor environments that closely mirror outdoor pollution dynamics [30]. These findings are directly relevant to Lagos, where residential buildings are frequently located within metres of informal roadblocks. Synthesising this evidence establishes a robust empirical basis for linking community-level combustion practices to indoor exposure burdens during lockdowns [35]. This synthesis supports extrapolation of indoor exposure dynamics to neighbourhood-scale security practices, while acknowledging uncertainty arising from measurement scarcity and heterogeneous building conditions across rapidly expanding urban districts [28] globally today.

6.2 Qualitative Community-Level Observations During Lockdowns

Community-level observations during lockdown periods provide granular insight into how security practices translated into lived exposure experiences. Residents frequently reported the establishment of informal roadblocks at street entrances, junctions, and access points located immediately adjacent to homes [33]. The spatial proximity of these sites meant that smoke plumes from burning tyres entered dwellings within minutes, often without warning.

Night-time burning was a recurrent feature of these practices. Combustion activities were commonly initiated during evening hours, when perceived security risks increased and enforcement visibility was prioritised [28]. Reduced atmospheric mixing and limited ventilation during these periods intensified indoor pollutant retention. Residents described closing windows and doors for safety, inadvertently trapping contaminated air indoors.

Prolonged burning practices were also observed. In some neighbourhoods, tyres were reignited repeatedly across successive nights, preventing complete clearance of pollutants between events [31]. This repetition transformed episodic exposures into chronic indoor contamination. Households located near roadblocks experienced persistent odours, soot deposition on interior surfaces, and respiratory discomfort.

These observations highlight the disconnect between security intent and environmental consequence. While roadblocks were perceived as protective, their operation imposed disproportionate exposure burdens on residents. Moving from observation toward comparative assessment enables evaluation of whether security benefits justified impacts [35].

6.3 Competing Public Health Risks During Pandemic Restrictions

Pandemic restrictions required policymakers and communities to balance multiple, often competing, public health risks. Measures designed to limit viral transmission prioritised movement restriction, physical barriers, and visible enforcement [30]. These strategies offered immediate benefits by reducing contact rates, yet they also reshaped environmental exposures in ways that were less apparent.

Combustion-based security practices exemplify this trade-off. While intended to deter movement and enhance compliance, tyre burning generated pollutants that infiltrated homes and accumulated indoors [32]. For residents confined indoors, exposure to particulate matter and toxic gases represented a parallel health risk operating alongside infectious disease threats.

Comparative risk assessment highlights the asymmetry between acute and chronic hazards. Viral transmission risks were immediate and widely communicated, whereas environmental exposure risks were diffuse, cumulative, and poorly recognised [28]. Evaluating pandemic responses through this dual-risk lens underscores the importance of integrating health considerations into emergency decision-making, rather than treating them as concerns [34].

Table 2: Comparison of Intended Security Benefits and Unintended Indoor Air Quality Consequences

Community Security Objective	Intended Security Benefit	Mechanism of Action	Unintended Indoor Air Quality Consequence	Public Health Implication
Informal roadblocks at neighbourhood entrances	Restriction of unauthorised movement	Physical obstruction of access routes	Proximity of roadblocks to residences facilitates pollutant infiltration	Increased indoor exposure to combustion-related pollutants
Tyre burning for visibility and deterrence	High-visibility enforcement presence	Dense smoke and odour signals compliance	Emission of PM _{2.5} , PM ₁₀ , VOCs, PAHs, and soot	Respiratory irritation and toxicological risk
Night-time burning practices	Enhanced night security perception	Sustained combustion during low-activity hours	Reduced dispersion and ventilation during nighttime	Prolonged indoor pollutant retention
Repeated ignition during lockdown periods	Continuous deterrence and access control	Episodic yet recurrent burning events	Cumulative indoor pollutant loading	Transition from acute to chronic exposure
Use of readily available waste materials	Rapid and low-cost enforcement	Unregulated combustion of synthetic materials	Release of complex toxic pollutant mixtures	Heightened inflammatory and cardiopulmonary risk
Community-led enforcement without oversight	Local autonomy and rapid response	Absence of formal regulation	Lack of exposure mitigation or guidance	Disproportionate impact on vulnerable populations
Closure of windows and doors for security	Reduced perceived external threat	Limitation of natural ventilation	Trapping of infiltrated pollutants indoors	Increased exposure duration
Concentration of enforcement at junctions	Efficient monitoring of movement	Spatial clustering near homes	Localised indoor pollution hotspots	Unequal exposure burden within communities

7. POLICY, PUBLIC HEALTH, AND URBAN GOVERNANCE IMPLICATIONS

7.1 Integrating Environmental Health into Emergency Security Planning

Emergency security planning during public health crises has traditionally prioritised immediate compliance and deterrence objectives, often with limited consideration of environmental health implications. The experience of lockdown-related community security practices highlights the need for anticipatory risk assessment frameworks that account for secondary exposure pathways [33]. Such frameworks would evaluate not only the effectiveness of security interventions but also their potential to generate environmental hazards within residential settings.

Anticipatory assessment requires early identification of practices likely to produce airborne emissions, particularly in dense urban environments where proximity between enforcement sites and dwellings is unavoidable [36]. Incorporating environmental health expertise into emergency planning can help anticipate how security measures interact with housing typologies, ventilation practices, and population vulnerability. This integration shifts planning from reactive mitigation toward preventive design.

Cross-sector coordination is central to this approach. Health authorities, environmental agencies, and security institutions often operate within parallel governance structures, limiting information exchange during emergencies [34]. Establishing formal coordination mechanisms would enable shared risk assessment, joint guidance development, and rapid response to emerging environmental concerns. During lockdowns, such coordination could have supported the identification of non-combustive enforcement alternatives and informed communities of associated health risks.

Environmental health integration also strengthens accountability. When security measures are assessed through a public health lens, responsibility for unintended consequences becomes clearer [38]. This transparency encourages decision-makers to weigh trade-offs explicitly rather than implicitly. Embedding environmental health criteria into emergency security protocols therefore represents a critical step toward reducing unintended indoor exposure risks while maintaining public safety objectives [35].

7.2 Alternatives to Combustive Community Security Measures

Reducing indoor air quality impacts requires the adoption of community security strategies that achieve visibility and access control without relying on combustion. Non-polluting visibility measures, such as reflective barriers, signage, and temporary physical markers, can delineate controlled areas effectively without generating emissions [37]. These approaches maintain the communicative function of roadblocks while eliminating pollutant sources. Lighting-based solutions offer additional benefits. Solar-powered streetlights, portable floodlights, and motion-activated lighting enhance visibility and deterrence during nighttime hours, addressing security concerns commonly cited as justification for tyre burning [33]. Improved lighting also contributes to broader urban safety and can be deployed rapidly with minimal environmental impact.

Community policing models provide a complementary strategy. Organised patrols, whistle systems, and communication networks enable local monitoring without material combustion [35]. These approaches leverage social cohesion rather than physical barriers, reducing reliance on environmentally harmful practices. In contexts where formal policing capacity is limited, community-based coordination supported by local authorities can offer effective alternatives.

Importantly, adoption of these measures requires institutional support. Providing communities with resources, guidance, and technical assistance increases the feasibility of non-polluting strategies [38]. When alternatives are accessible and visible, reliance on combustion-based practices diminishes. Evaluating and promoting these options transforms security from an environmental liability into a component of sustainable urban governance [34].

7.3 Risk Communication and Community Awareness

Risk communication plays a critical role in mitigating indoor air quality impacts arising from community security practices. Many residents are unaware of how outdoor combustion activities translate into indoor exposure, particularly during periods of prolonged confinement [36]. Clear, accessible messaging can help communities recognise health risks associated with tyre burning and similar practices.

Educational efforts should focus on practical guidance, such as recognising high-exposure periods, improving ventilation when feasible, and advocating for non-polluting security measures [33]. Community leaders and local organisations serve as effective intermediaries for disseminating information and shaping collective norms.

Effective communication also supports behavioural change by aligning security objectives with health protection. When residents understand the trade-offs involved, they are more likely to support alternative strategies [37]. This awareness creates a foundation for forward-looking approaches that integrate safety, health, and environmental sustainability into community decision-making, leading naturally toward longer-term resilience strategies [38].

Figure 3: Integrated Policy Framework for Managing Community Security Without Compromising Indoor Air Quality



Figure 3: Integrated policy framework for managing community security without compromising indoor air quality

8. FUTURE RESEARCH DIRECTIONS AND IMPLEMENTATION CHALLENGES

8.1 Data Gaps in Indoor Air Quality During Emergencies

One of the most significant limitations in addressing indoor air quality risks during emergencies is the absence of timely, context-specific data. Existing air quality monitoring frameworks are predominantly oriented toward ambient outdoor pollution and industrial sources, offering limited insight into indoor exposure conditions during crisis periods [36]. As a result, the magnitude and distribution of indoor pollutant exposure arising from informal activities often remain undocumented.

Real-time monitoring is particularly lacking at the community scale. Emergency conditions such as lockdowns alter emission patterns, mobility, and ventilation behaviours, rendering conventional exposure assumptions unreliable [39]. Without rapid monitoring tools, short-lived but intense pollution events such as combustion associated with community security practices are easily overlooked. Portable sensors and low-cost monitoring technologies offer potential solutions but remain underutilised in densely populated urban neighbourhoods.

Community-scale exposure assessment represents another critical gap. Most existing studies rely on limited household measurements or proxy indicators, failing to capture spatial variability within neighbourhoods [37]. Differences in proximity to emission sources, building characteristics, and ventilation practices produce heterogeneous exposure profiles that require fine-grained analysis. During emergencies, these disparities may widen as mobility restrictions constrain individual coping strategies.

Addressing these data gaps is essential for evidence-based intervention. Improved monitoring would enable early identification of high-risk practices and support targeted risk communication [40]. Strengthening data collection during emergencies therefore constitutes a foundational step toward protecting indoor environmental health under crisis conditions [38].

8.2 Translating Evidence into Enforceable Urban Practice

Even where evidence of indoor air quality risks exists, translating knowledge into enforceable urban practice presents substantial challenges. Institutional barriers remain a primary constraint. Responsibilities for public health, environmental protection, and community security are often distributed across agencies with limited coordination [36]. This fragmentation hinders the development of integrated response strategies that address environmental consequences of emergency actions.

Enforcement capacity is further constrained in informal settlements, where regulatory reach is limited and governance structures are decentralised [41]. Many community security practices operate outside formal legal frameworks, complicating efforts to regulate or prohibit environmentally harmful activities. Interventions that rely solely on enforcement may therefore prove ineffective or socially counterproductive.

Practical translation of evidence requires context-sensitive approaches. Guidelines must account for resource limitations, housing density, and reliance on informal governance mechanisms [38]. Rather than imposing uniform prohibitions, policy responses should prioritise harm reduction, provision of alternatives, and community engagement. Supporting non-combustive security strategies and offering technical assistance can facilitate behaviour change without undermining local autonomy.

Bridging the gap between evidence and practice ultimately depends on institutional learning. Emergencies provide opportunities to integrate environmental health considerations into urban governance frameworks [39]. By embedding lessons from crisis periods into planning and regulation, cities can strengthen resilience while reducing the likelihood that future emergencies generate avoidable indoor exposure risks [37].

9. CONCLUSION

9.1 Synthesis of Key Findings

This study demonstrates a clear and consequential link between informal community security practices during lockdown periods and unintended indoor air pollution. Measures adopted to regulate movement and enhance neighbourhood safety, particularly tyre burning at informal roadblocks, generated significant quantities of particulate matter and toxic gases that readily infiltrated nearby residential spaces. Once indoors, these pollutants accumulated due to limited ventilation, surface adsorption, and prolonged indoor occupancy, transforming episodic outdoor combustion events into sustained exposure scenarios.

The analysis highlights how security intent and environmental outcome diverged sharply under emergency conditions. Practices designed to protect communities from immediate threats inadvertently introduced chronic respiratory and toxicological risks, especially for households located near access points and junctions. These risks were amplified by housing density, reliance on natural ventilation, and the absence of regulatory oversight. Rather than isolated incidents, the findings point to a systemic pattern in which informal governance mechanisms interacted with urban infrastructure to reshape exposure pathways.

Lagos-specific public health implications are particularly pronounced. High population density, heterogeneous housing typologies, and socioeconomic constraints limited residents' ability to mitigate exposure. Children, older adults, and individuals with respiratory conditions bore disproportionate health burdens due to extended confinement and heightened vulnerability. The study underscores that indoor air quality during emergencies is not merely a technical issue, but a function of social organisation, spatial proximity, and governance context. Recognising these interdependencies is essential for understanding how crisis responses translate into long-term public health consequences in rapidly urbanising cities.

9.2 Final Reflections on Pandemic Preparedness and Environmental Justice

Pandemic preparedness frameworks must account for the potential generation of secondary harms alongside primary health objectives. The experience examined here illustrates how well-intentioned emergency responses can produce environmental exposures that undermine community health, particularly when informal practices operate outside regulatory scrutiny. Avoiding such outcomes requires anticipation rather than reaction.

Environmental justice considerations are central to this challenge. Populations with limited housing choice and political voice are more likely to experience compounded risks during crises. Integrated, health-protective urban governance must therefore align security, public health, and environmental objectives, ensuring that emergency measures do not externalise harm onto already vulnerable communities.

Moving forward, preparedness strategies should prioritise non-polluting security alternatives, proactive risk communication, and institutional coordination that embeds environmental health into crisis planning. By doing so, cities can strengthen resilience while safeguarding indoor environments, ensuring that responses to future emergencies protect both immediate safety and long-term well-being.

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