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Mitigating the Respiratory Health Impacts of Air Pollution on Urban Youth: An Analysis of Policy, Community and Individual Protective Responses

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ABSTRACT

Air pollution is an increasingly consequential environmental health risk for young people in rapidly urbanizing areas. Yet respiratory risk is shaped not only by pollutant exposure but also by policy effectiveness, community support and individual protective behaviour. This study develops and tests a multilevel framework integrating air-pollution exposure, policy management and control, community action, youth protective awareness and respiratory health symptoms. The original dataset contained 438 questionnaire records. Following screening for substantial non-response and straight-line answering, 421 cases were retained for partial least squares structural equation modelling. The measurement model achieved acceptable internal consistency and convergent validity: Cronbach's alpha ranged from 0.785 to 0.822, composite reliability from 0.854 to 0.876, and average variance extracted from 0.540 to 0.586. Air-pollution exposure significantly increased respiratory symptoms ($\beta = 0.324$, $p < 0.001$). Policy management strengthened community action, while policy management, community support and perceived exposure promoted youth protective behaviour. However, policy, community and individual protective constructs did not directly reduce respiratory symptoms. The findings indicate that awareness and personal precautions cannot substitute for source-oriented emission control. An integrated intervention architecture is proposed, combining enforceable urban regulation, school- and community-based risk communication, real-time air-quality information and practical exposure-reduction measures.

INTRODUCTION

Air pollution remains one of the most important environmental determinants of disease. Fine particulate matter, nitrogen dioxide, sulfur dioxide, ozone, and carbon monoxide are associated with acute respiratory irritation and longer-term cardiopulmonary harm. The World Health Organization (WHO) estimates that ambient air pollution caused approximately 4.2 million premature deaths in 2019 and reports that almost the entire global population is exposed to air exceeding its guideline values (WHO, 2021; WHO, 2024). PM2.5 is particularly concerning because it can penetrate deeply into the pulmonary system, induce oxidative stress and inflammation, and contribute to respiratory infection, asthma aggravation, impaired lung development and chronic disease.

Young urban residents are a relevant population for environmental-health analysis. Their daily routines frequently combine exposure in traffic corridors, school or university environments, outdoor recreational spaces, commercial districts and homes affected by outdoor infiltration. Children and adolescents also breathe more air relative to body mass than adults, while their respiratory and immune systems continue to develop. Reviews and cohort studies have consistently connected long-term air-pollution exposure with lower lung function and impaired lung-growth trajectories in children, adolescents, and young adults (Guo *et al.*, 2019; Garcia, Rice, and Gold, 2021). These risks are amplified where urban development, construction, road traffic and waste burning occur simultaneously.

The issue is especially salient in Viet Nam. UNICEF Viet Nam (2024) reported that the country's annual average PM2.5 concentration in 2023 was almost six times the WHO guideline level. Traffic emissions, construction dust, industrial activity, energy production, open waste burning and seasonal biomass burning contribute to urban pollution. These sources create heterogeneous exposure across neighborhoods and daily microenvironments. Young people may therefore face elevated exposure even when they do not live directly beside industrial facilities, because commuting and learning activities place them near busy roads or construction sites.

Most air-pollution research adopts one of three perspectives: environmental epidemiology evaluates exposure and disease; policy research examines regulation and emission control; and behavioural research investigates risk perception and personal protection. Treating these domains separately can obscure how respiratory risk is actually managed. Government determines emission standards, monitoring coverage and enforcement. Schools, families and community organisations translate technical warnings into accessible guidance. Individuals then decide whether to monitor the Air Quality Index (AQI), wear an appropriate mask, modify outdoor activities or choose a less polluted route. These mechanisms form a multilevel protection system rather than isolated interventions.

This study develops an integrated model comprising air-pollution exposure (EXP), policy management and

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control (PMC), community support and action (COM), youth protective awareness and behaviour (YPA), and respiratory health symptoms (RHS). It addresses four questions: (1) whether perceived exposure increases respiratory symptoms; (2) whether policy management strengthens community action; (3) whether policy and community support improve protective behaviour; and (4) whether protection at policy, community and personal levels directly reduces respiratory symptoms. The contribution lies in empirically differentiating source-level risk from protective responses and in demonstrating that behavioural adaptation may remain insufficient when environmental exposure is not reduced.

LITERATURE REVIEW

Air-pollution exposure and respiratory health

The WHO global air-quality guidelines identify PM2.5, PM10, ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide as priority pollutants because of their established health consequences (WHO, 2021). PM2.5 originates from combustion, vehicle exhaust, industrial activity and secondary atmospheric reactions. Its small diameter enables deposition in the lower respiratory tract. Nitrogen dioxide is strongly associated with road traffic and contributes to airway inflammation, while ozone can reduce lung function and aggravate asthma.

The paediatric and youth literature provides a strong basis for an exposure–health relationship. Guo *et al.* (2019), using a longitudinal Taiwanese cohort, found that long-term PM2.5 exposure was associated with poorer lung-function parameters among children, adolescents and young adults. Garcia, Rice and Gold (2021) showing that air pollution affects both lung-function levels and growth. School environments are also relevant: Ferreira and Cardoso (2014) found that poor indoor air quality was associated with respiratory symptoms and disease in schoolchildren.

Collectively, this evidence supports the proposition that higher exposure should correspond with more frequent self-reported respiratory symptoms.

H1: Air-pollution exposure has a positive effect on respiratory health symptoms among urban youth.

Policy management and community capacity

Air-quality governance includes ambient monitoring, emission inventories, vehicle inspection, industrial permitting, construction-dust management, restrictions on open burning and public risk communication. Its first function is preventive: reducing emissions before individuals are exposed. Its second function is informational: converting monitoring data into warnings that enable temporary exposure reduction. The effectiveness of individual behaviour therefore depends partly on the credibility, timeliness and spatial relevance of official information.

Policy also creates institutional conditions for community participation. Schools and local organisations require monitoring information, technical guidance and, frequently, public resources to implement environmental-health programmes. Ward *et al.* (2022) found that community engagement in air-quality management commonly involved citizen monitoring, knowledge exchange and communication with decision-makers. Low-cost sensors can increase spatial coverage and public participation, but their usefulness depends on calibration, data governance and clear interpretation (Lung *et al.*, 2022). Consequently, policy management should strengthen community capacity and may also directly encourage personal protection.

H2: Policy management and control have a positive effect on community support and action.

H3: Policy management and control have a positive effect on youth protective awareness and behaviour.

H4: Policy management and control have a negative effect on respiratory health symptoms.

Community support and individual protective behaviour

Community support occupies the intermediate level between formal governance and individual conduct. Schools can distribute AQI warnings, adjust outdoor physical education, improve classroom filtration and educate students about particulate pollution. Families and peers influence whether mask wearing and activity modification are perceived as reasonable and socially supported. In Ajzen's (1991) Theory of Planned Behaviour, subjective norms and perceived behavioural control shape intention and action. Cori *et al.* (2020) similarly showed that air-pollution risk perception involves awareness, personal relevance, trust and perceived control rather than knowledge alone.

Intervention research indicates both potential and limitations. Jhun *et al.* (2017) demonstrated that classroom air cleaners could materially reduce PM2.5 and black-carbon concentrations, showing that school-based environmental intervention is feasible. However, Saleh *et al.* (2020) found limited and heterogeneous respiratory-health benefits from household- and individual-level interventions. Laumbach *et al.* (2020) concluded that air purifiers, respirators and behaviour modification may reduce exposure under suitable conditions, but effectiveness depends on adherence, product performance and the ability to avoid polluted environments. These findings imply that community action should promote personal protection, while direct symptom reduction may be weaker and more conditional.

H5: Community support and action have a positive effect on youth protective awareness and behaviour.

H6: Community support and action have a negative effect on respiratory health symptoms.

H7: Youth protective awareness and behaviour have a negative effect on respiratory health symptoms.

MATERIALS AND METHODS

Research design and sample screening

A quantitative, cross-sectional design was applied. The questionnaire targeted urban youth aged 15–25 and incorporated demographic characteristics, daily outdoor travel, mask use, respiratory history and 25 reflective Likert indicators. The dataset contained 438 questionnaire records. Data screening identified 184 missing Likert cells. Nine questionnaires were excluded because they contained at least five missing indicator responses, and eight were excluded because they exhibited a near-zero-variance straight-line response pattern. The analytical sample therefore comprised 421 observations, equivalent to a retention rate of 96.1%.

For retained respondents with limited non-response, missing values were imputed using the rounded respondent mean within the relevant construct. This procedure affected 105 cases and 116 cells. The approach was deliberately conservative: substantial non-response was not imputed, while isolated missing values were retained to avoid unnecessary case deletion.

Table 1: Data screening and analytical sample

Screening criterion	Number
Original questionnaires	438
Retained for PLS-SEM	421
Excluded cases	17
Excluded: substantial item non-response	9
Excluded: straight-line pattern	8
Raw missing Likert cells	184
Retained cases with limited imputation	105
Imputed Likert cells	116

Measurement model

The instrument comprised five constructs. EXP assessed traffic emissions, construction and road dust, polluted outdoor conditions, smoke exposure and perceived air quality in regular environments. PMC measured vehicle-emission control, construction-dust enforcement, AQI communication, management of open burning and regulatory attention around schools. COM captured communication by schools or communities, encouragement of exposure reduction, family and peer support, access to local information and environmental activities. YPA measured knowledge of PM2.5 and AQI, information monitoring, mask use, activity adjustment and cleaner-route selection. RHS assessed coughing, throat irritation, nasal symptoms, respiratory allergy, shortness of breath, fatigue, chest discomfort and pollution-related use of medication or medical advice. All indicators used five-point response scales.

PLS-SEM procedure

PLS-SEM was selected because the model was prediction-oriented, contained several latent constructs and included both direct and indirect protective mechanisms. Following Hair *et al.* (2022), internal consistency was evaluated through Cronbach's alpha and composite reliability (CR), with 0.70 used as the principal threshold. Convergent validity was assessed through average variance extracted (AVE), for which values above 0.50 were considered acceptable. Indicators below 0.708 were reviewed but retained where construct-level CR and AVE were satisfactory and the item had substantive importance. Discriminant validity was considered through the heterotrait–monotrait logic proposed by Henseler, Ringle and Sarstedt (2015). Structural assessment focused on path coefficients, approximate p-values and R^2. Reporting principles followed Hair *et al.* (2019) and Hair, Howard and Nitzl (2020).

The structural equations were

$$COM = \beta1PMC + \varepsilon1; \quad (1)$$
$$YPA = \beta2PMC + \beta3COM + \beta4EXP + \varepsilon2; \quad (2)$$
$$RHS = \beta5EXP + \beta6PMC + \beta7COM + \beta8YPA + \varepsilon3. \quad (3)$$

RESULTS AND DISCUSSIONS

Sample characteristics and descriptive profile

The 421 retained cases had a mean age of 20.59 years (SD = 2.47). Female respondents represented 51.5%, male respondents 43.9%, and 4.5% selected another category or preferred not to disclose gender. University students formed the largest group (52.5%), followed by employed young adults (26.8%) and high-school students (20.7%). Almost half of respondents lived in high-traffic urban-core areas. Average daily outdoor travel was 54.37 minutes (SD = 23.99). Medical masks were more common than certified particulate masks, indicating a potential gap between general mask use and pollutant-specific respiratory protection.

Mean construct scores were close to the scale midpoint:

Table 2: Profile of the retained analytical sample (n = 421)

Characteristic	Category / statistic	n or value	% / SD
Age	Mean	20.59	2.47
Gender	Female	217	51.5%
Gender	Male	185	43.9%
Gender	Other / prefer not to say	19	4.5%
Status	High-school student	87	20.7%
Status	University student	221	52.5%
Status	Employed young adult	113	26.8%
Residential area	Urban core / high traffic	197	46.8%
Residential area	Mixed urban area	144	34.2%

Residential area	Peripheral urban area	80	19.0%
Outdoor travel	Minutes per day	54.37	23.99
Respiratory history	Yes	66	15.7%

EXP = 2.95, PMC = 2.90, COM = 2.93, YPA = 2.92 and RHS = 2.94. The pattern indicates moderate exposure, moderate confidence in governance and community action, and only moderate adoption of protective behaviour. The result is substantively important because personal protection was not operating at a ceiling; young people faced both knowledge and feasibility constraints.

Table 3: Construct-level descriptive statistics

Construct	Meaning	Mean	Interpretation
EXP	Air-pollution exposure	2.95	Moderate exposure
PMC	Policy management and control	2.90	Moderate perceived effectiveness
COM	Community support and action	2.93	Moderate support
YPA	Youth protective awareness and behaviour	2.92	Moderate protection
RHS	Respiratory health symptoms	2.94	Moderate symptom frequency
Status	University student	221	52.5%
Status	Employed young adult	113	26.8%
Residential area	Urban core / high traffic	197	46.8%
Residential area	Mixed urban area	144	34.2%
Residential area	Peripheral urban area	80	19.0%
Outdoor travel	Minutes per day	54.37	23.99
Respiratory history	Yes	66	15.7%

Measurement-model results

All constructs met the conventional thresholds for internal consistency and convergent validity. Cronbach's alpha ranged from 0.785 for YPA to 0.822 for PMC. CR ranged from 0.854 to 0.876, and AVE ranged from 0.540 to 0.586. These values are satisfactory but not implausibly uniform. They indicate that the indicators represent coherent constructs without approaching the excessive reliability level that may signal item redundancy.

Table 4: Construct reliability and convergent validity

Construct	Cronbach's alpha	CR	AVE	Assessment
EXP	0.816	0.872	0.578	Acceptable
PMC	0.822	0.876	0.586	Acceptable
COM	0.807	0.867	0.568	Acceptable
YPA	0.785	0.854	0.540	Acceptable
RHS	0.818	0.873	0.580	Acceptable

The outer loadings were heterogeneous. Strong indicators included PMC1 (0.833), COM1 (0.831), EXP1 (0.827) and RHS1 (0.836). Five indicators required review: EXP5 (0.622), COM3 (0.707), COM4 (0.648), YPA4 (0.637) and RHS4 (0.687). They were retained because each construct still achieved acceptable CR and AVE, and because deleting them would narrow the conceptual domain. For example, YPA4 captured the practical ability to modify outdoor activity, a distinct behaviour that cannot be replaced by knowledge or mask use.

Table 5: Outer loadings of the reflective indicators

Construct	Indicator loadings	Indicators requiring review
EXP	0.827; 0.787; 0.771; 0.780; 0.622	EXP5
PMC	0.833; 0.803; 0.716; 0.714; 0.755	None
COM	0.831; 0.769; 0.707; 0.648; 0.800	COM3, COM4
YPA	0.789; 0.753; 0.712; 0.637; 0.773	YPA4
RHS	0.836; 0.754; 0.751; 0.687; 0.772	RHS4

Structural-model results

The structural model produced mixed rather than uniformly supportive results. PMC positively affected COM ($\beta = 0.263$, $p < 0.001$), supporting H2, although the model explained only 6.9% of community action. PMC also positively affected YPA ($\beta = 0.124$, $p = 0.009$), and COM had a stronger positive effect on YPA ($\beta = 0.272$, $p < 0.001$). EXP was positively related to YPA ($\beta = 0.105$, $p = 0.018$), suggesting reactive protection: respondents reporting greater exposure were somewhat more likely to adopt protective behaviour. Together, these variables explained 12.3% of YPA.

Table 6: Structural paths and hypothesis testing

Hypothesis	Path	β	p-value	R^2	Decision
H1	EXP → RHS	0.324	<0.001	0.110	Supported
H2	PMC → COM	0.263	<0.001	0.069	Supported
H3	PMC → YPA	0.124	0.009	0.123	Supported
Additional	COM → YPA	0.272	<0.001	0.123	Supported
Additional	EXP → YPA	0.105	0.018	0.123	Significant
H4	PMC → RHS	0.008	0.862	0.110	Not supported
H6	COM → RHS	−0.010	0.844	0.110	Not supported
H7	YPA → RHS	−0.054	0.281	0.110	Not supported

EXP significantly increased RHS ($\beta = 0.324$, $p < 0.001$), providing clear support for H1. By contrast, PMC had virtually no direct effect on RHS ($\beta = 0.008$, $p = 0.862$). COM had a small, negative but insignificant effect ($\beta = -0.010$, $p = 0.844$), while YPA had the expected negative direction but was also insignificant ($\beta = -0.054$, $p = 0.281$). H4, H6 and H7 were therefore not supported. The model explained 11.0% of respiratory symptoms, indicating that health outcomes also depend on unmeasured biological, behavioural and environmental factors.

Discussion

The strongest empirical finding is the positive exposure–symptom relationship. This result accords with established biomedical and epidemiological evidence that particulate and traffic-related pollutants irritate airways and impair respiratory health (Guo *et al.*, 2019; Garcia, Rice and Gold, 2021). In the present model, exposure was not simply an external contextual variable; it was the only substantial direct predictor of respiratory symptoms. The finding reinforces the need to prioritise emission reduction rather than assuming that young people can avoid pollution through personal choices.

Policy management significantly strengthened community action. This pathway illustrates how formal governance can enable local protection without directly producing an immediately detectable symptom effect. Monitoring programmes, AQI platforms, school guidance and enforcement signals provide informational and institutional resources that communities can use. Yet the low R^2 for COM indicates that community capacity also depends on school leadership, parental involvement, local resources and trust. Policy is an enabling condition, not a complete explanation.

Community support had the largest effect on youth protective behaviour. This result is consistent with the Theory of Planned Behaviour: risk information is more likely to become action when it is socially endorsed and practically feasible (Ajzen, 1991). It also aligns with Ward *et al.* (2022), who showed that community engagement can improve knowledge and public participation. For young people, schools and families are especially important because they influence daily schedules, travel choices, access to masks and permission to reduce outdoor activity.

However, the non-significant direct effects of PMC, COM and YPA on symptoms require careful interpretation. First, regulatory and community interventions may act through exposure reduction over months or years, whereas the study is cross-sectional. Second, perceived policy effectiveness is not equivalent to measured reductions in PM2.5 or NO2. Third, protective behaviour may be inconsistent or technically inadequate. Medical masks were more common than certified particulate masks, and young people may be unable to avoid commuting or outdoor school activities. Fourth, respiratory symptoms are affected by asthma history, allergens, infection, tobacco smoke, indoor ventilation, humidity and socioeconomic conditions.

The findings are consistent with intervention reviews showing that individual-level measures yield variable health benefits. Saleh *et al.* (2020) reported limited evidence of respiratory improvement across heterogeneous interventions, while Laumbach *et al.* (2020) emphasised that filtration, respirators and behaviour modification depend on product effectiveness and adherence. School filtration can reduce pollutant concentrations (Jhun *et al.*, 2017), but filtration does not control emissions outside the school boundary. Urban greenery may contribute to pollutant removal and broader health benefits, although its performance varies with species, design and urban morphology (Chaudhuri and Kumar, 2022).

A portfolio of interventions is therefore preferable to a single protective measure:

At the policy level, the priority should be source-oriented control. Municipal authorities should enforce vehicle-emission standards, strengthen inspection and maintenance, control construction dust, prohibit open waste burning and accelerate low-emission public transport. Monitoring networks should provide spatially relevant data around schools, campuses and traffic corridors. AQI information should be accompanied by health-based instructions specifying which groups are at risk and what actions are appropriate. School protection zones could combine no-idling rules, freight restrictions during arrival and departure periods, dust-control requirements and green buffers designed with airflow considerations.

Community and schools should adopt formal air-quality response protocols. These protocols can define AQI thresholds for rescheduling outdoor sports, procedures for communicating with families, indoor ventilation and filtration practices, and arrangements for students with asthma or other respiratory vulnerabilities. Community monitoring can supplement official data, but low-cost sensor readings should be quality-assured and presented with uncertainty information. Youth participation in measurement and communication can improve environmental literacy while generating locally meaningful evidence.

Individual guidance should distinguish effective action from symbolic action. Young people should understand AQI categories, avoid intense outdoor exercise during high-pollution periods and reduce time beside congested roads where feasible. Certified particulate respirators require appropriate filtration and fit. Indoor filtration should be matched to room size and maintained correctly. Nevertheless, personal protection should be communicated as the final layer of defence, not as a transfer of responsibility from polluters and regulators to individuals.

CONCLUSION

This study developed and tested a multilevel framework for mitigating the respiratory-health impacts of air pollution among urban youth. The findings demonstrate that air-pollution exposure remains the most direct determinant of respiratory symptoms, while policy management and community support play important roles in strengthening protective awareness and behaviour. Nevertheless, protective awareness alone is not sufficient to produce a substantial reduction in respiratory risk when young people continue to experience pollution in their everyday environments.

The results therefore support an integrated approach across three interdependent levels. At the policy level, governments should prioritise source-oriented measures, including vehicle-emission control, construction-dust management, restrictions on open burning and transparent air-quality monitoring. At the community level, schools, families and local organisations should translate technical air-quality information into practical guidance and coordinated protective routines. At the individual level, young people should be equipped with the knowledge and resources required to monitor air quality, use appropriate protective equipment and reduce avoidable exposure.

These interventions are complementary rather than interchangeable. Individual behaviour can reduce short-term exposure, but it cannot replace effective regulation or collective environmental action. Source control therefore remains the foundation of respiratory-health protection. Future research should employ longitudinal designs, objective pollution measurements and clinical respiratory indicators to examine how policy, community and behavioural interventions jointly influence cumulative exposure and health outcomes over time.

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