Predicting Indoor Air Pollution Reduction Behavior Among Urban Residents of Bangladesh Using an Extended Theory of Planned Behavior (TPB) Model

Marvina Rahman Ritu[1,2*], Muhammad Mainuddin Patwary[1,2], Afif Iftikhar[1,2], Md Ismay Azam Badhon[1,2], Mondira Bardhan[1,3], Imran Chowdhury Sakib[1,2], Dana Sikder[1,2], Md Pervez Kabir[1,4]

[1]Environment and Sustainability Research Initiative, Khulna 9208, Bangladesh
[2]Environmental Science Discipline, Life Science School, Khulna University, Khulna 9208, Bangladesh
[3]Department of Park, Recreation and Tourism Management, Clemson University, Clemson, SC, USA
[4]Department of Civil Engineering, University of Ottawa, Ottawa, K1N 6N5, Canada

***Corresponding author:**
Marvina Rahman Ritu
Environment and Sustainability Research Initiative, Khulna 9208, Bangladesh.
Email: marvina.ritu16@gmail.com
ORCID: 0000-0002-6746-7188

Predicting Indoor Air Pollution Reduction Behavior Among Urban Residents of Bangladesh Using an Extended Theory of Planned Behavior (TPB) Model

Abstract

Indoor air pollution (IAP), with elevated levels of fine particulate matter, significantly impacts public health in low- and middle-income countries (LMICs) such as Bangladesh where reliance on biomass fuels and inadequate ventilation leads to high pollutant concentrations exceeding World Health Organization (WHO) guidelines. While technological interventions have been explored, behavioral determinants of IAP reduction remain largely underexplored. Therefore, this study investigated the psychosocial determinants of indoor air pollution reduction behaviors among 410 urban residents in Bangladesh using an extended Theory of Planned Behavior (TPB) model following a cross-sectional study design via a 35-item structured online questionnaire. Confirmatory factor analysis (CFA) and structural equation modelling (SEM) were used to test the measurement model's reliability and validity. The SEM results indicated significant positive associations of attitude (AT) ($\beta = 0.836$, $p < 0.001$), subjective norm (SN) ($\beta = 0.430$, $p < 0.001$), perceived behavioral control (PBC) ($\beta = 0.334$, $p = 0.004$), environmental concern (EC) ($\beta = 0.661$, $p < 0.001$), and actual behavior (AB) ($\beta = 0.832$, $p < 0.001$) with behavioral intention (BI). Moderation analysis showed that PBC moderated the relationships between AT and BI ($\beta = –0.386$, $p = 0.045$) and between SN and BI ($\beta = –0.437$, $p = 0.021$), with higher PBC linked to stronger BI regardless of AT or SN levels. Our findings highlight the significance of enhancing public health efforts in resource-limited urban settings, with interventions that strengthen behavioral control, promote environmental awareness, and social norms may enhance sustainable practices to reduce IAP.

Keywords: Indoor air pollution; Theory of Planned Behavior; Urban area; Behavioral intention; Pro-environmental behavior

1. Introduction

Air pollution is a major global health concern linked to premature mortality and increased risks of respiratory and cardiovascular diseases (Dedoussi et al. 2020; Khomenko et al. 2021). Rapid urbanization and industrialization have intensified emissions of particulate matter (PM), nitrogen oxides (NO_x), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), volatile organic compounds (VOCs), and heavy metals, all of which adversely affect human health (Chan and Yao, 2008; Liang and Yang, 2019; Shi et al., 2017a, Domingo and Rovira, 2020; Khajeamiri et al., 2021; Manisalidis et al., 2020). Indoor air quality (IAQ), though often overlooked, is equally critical (Kumar et al., 2023; Yasmin et al., 2024). In low- and middle-income countries (LMICs), indoor pollution induced primarily from biomass combustion, cooking, and poor ventilation, substantially contributes to $PM_{2.5}$ exposure (Alhajeri et al. 2024; Pekey et al. 2013). Fine particulate matter penetrates deep into the lungs, causing damage to the respiratory (Liu et al. 2017; Sun et al. 2018) and cardiovascular systems (Zhang et al. 2022). Long-term exposure to $PM_{2.5}$ is associated with higher risks of heart disease (Wang et al. 2021; Weichenthal et al. 2016), strokes (Alexeeff et al. 2021), lung cancer (Yang et al. 2022) and all-cause mortality (Liu et al., 2022). Additionally, VOCs, NO_2, CO, and heavy metals in indoor air pose serious health risks, including neurotoxicity and carcinogenicity (Vardoulakis et al. 2020).

Approximately 40% of the global population continues to rely on solid biomass fuels—such as wood, agricultural residues, and animal dung—for cooking and heating, with dependency rates reaching 80–90% in Sub-Saharan Africa and South Asia (Adili Y 2018; Habermehl 2007; Timilsina and Malla 2021). The combustion of these fuels emits substantial indoor air pollutants, exposing an estimated 3 billion people worldwide to poor indoor air quality (Holgate 2017). This exposure has significant health consequences, contributing to between 2.8 and 4.3 million premature deaths annually, or approximately 7.7% of global mortality, predominantly through its impact on respiratory and cardiovascular systems, primarily caused by $PM_{2.5}$ (Fehintola, 2021; Johnson et al., 2022). In Bangladesh, indoor $PM_{2.5}$ concentrations have been reported to average around 190 μg/m³, significantly exceeding the WHO's recommended limit of 25 μg/m³ (Gurley et al., 2013), with biomass burning and fossil fuel combustion identified as major sources (Hossain 2019; Rahman et al. 2020). During cooking, the use of biomass stoves can elevate $PM_{2.5}$ levels beyond 1000 μg/m³ (Salje et al. 2014). Fuel use is stratified by socioeconomic status, with higher-income households more likely to use cleaner fuels like LPG, while lower-income groups depend on polluting biomass fuels (Ahmad, Kiran, and Alamgir 2023; Begum, Hopke, and Markwitz 2013). The health risks from indoor air pollution are compounded by factors such as cooking duration, type of fuel, exposure time, and concentration, which affect both the cooking area and the broader household environment (Alam et al. 2022; Amadu et al. 2023). Moreover, other indoor air pollution sources include cooking duration exposure, housing materials, and ventilation practices, such as the opening of windows and doors (Raju, Siddharthan, and McCormack 2020; Saraga et al. 2023; Tran, Park, and Lee 2020). Additional contributors to indoor $PM_{2.5}$ include inadequate ventilation, small kitchen spaces, absence of chimneys, poor housing materials, and cooking practices (Dai et al., 2018; Gurley et al., 2013; Q. Liu et al., 2022). Moreover, emissions from tobacco smoking, burning candles or oil lamps, kerosene use, kitchen location, building materials, and residential fireplaces and fuel-burning space heaters further worsen indoor air quality by releasing $PM_{2.5}$ and PM_{10} (Kurata, Takahashi, and Hibiki 2020; Ram et al. 2014; S. Dasgupta, Huq, M Khaliquzzaman, et al. 2006; Alam et al. 2022).

Conventional strategies to reduce air pollution have largely relied on technological and infrastructural interventions, including clean cook stove adoption, electrification, enhanced fuel standards, and the use of air purification systems (Chowdhury et al. 2024; Irfan, Cameron, and Hassan 2021). However, they are often inaccessible in LMICs due to economic and infrastructural limitations (Ali and Burhan 2024; Wang et al. 2024). Consequently, millions remain exposed to unsafe levels of air pollutants, particularly within household settings. In such contexts, behavioral strategies such as switching to cleaner fuels, enhancing ventilation, or modifying cooking routines represent viable, cost-effective, and urgently needed alternatives (Imarhiagbe, Nwodo, and Ogwu 2024; Rawat and Kumar 2023; Salje et al. 2014). To understand the mechanisms underlying such behavior, Ajzen's Theory of Planned Behavior (TPB) offers a rational and hedonistic decision-making model that emphasizes how attitudes, subjective norms, and perceived behavioral control shape behavioral intentions, rather than behavior directly (Ajzen, 1991; Bamberg and Möser, 2007). The TPB has been widely applied in environmental psychology and public health to predict various pro-environmental behaviors, including household energy conservation (Liu et al. 2021), air pollution reduction behavior (Shi, Fan, and Zhao 2017; Shi, Wang, and Zhao 2017a; Hung, Chang, and Shaw 2019), sustainable transportation choices (Acheampong 2017), and adoption of clean cooking technologies (Pakravan and MacCarty 2020).

Despite its proven applicability, behavioral research on air pollution mitigation, particularly within indoor environments, remains fragmented and underdeveloped. Much of the existing literature has concentrated on ambient air pollution (Sánchez-García et al. 2021; Cheng et al. 2022; Shi, Fan, and Zhao 2017; Shi, Wang, and Zhao 2017b; Woo et al. 2023; Park, Kim, and Yun 2022; Ru, Qin, and Wang 2019; Jeon, Kim, and Kim 2024), paying insufficient attention to the behavioral, cognitive, and normative processes that shape indoor exposure risk. This is a critical oversight, particularly in LMICs like Bangladesh, where households are routinely exposed to hazardous levels of indoor $PM_{2.5}$ due to biomass fuel use, poor ventilation, and entrenched cooking practices (Akteruzzaman et al. 2023; Susmita Dasgupta et al. 2006; Yasmin et al. 2024). Yet, the few existing studies on indoor air pollution (IAP) in Bangladesh are largely descriptive or policy-focused, rarely grounded in behavioral theory or informed by models such as TPB. Constructs such as perceived control, environmental concern, and social norms which are central to understanding behavioral intentions, remain underexplored in this domain (S. Dasgupta, Huq, M. Khaliquzzaman, et al. 2006). Amid rising calls for more theory-driven research on environmental health behavior (Liu et al., 2018; Pronello and Gaborieau, 2018; Shi et al., 2017a), there is an urgent need to better understand how psychosocial factors relate to individual action, particularly in resource-limited and high-risk settings. Recognizing this gap, this study applies an extended Theory of Planned Behavior model to assess the behavioral intentions of urban residents in Bangladesh regarding indoor air pollution reduction. The model builds upon the core TPB framework including attitudes, subjective norms, and perceived behavioral control by integrating environmental knowledge, environmental concern, and prior behavior. By quantifying the relative contribution of these constructs to behavioral intention, the study offers a comprehensive analysis of the determinants of indoor air pollution reduction behavior and provides empirical evidence to support the design of more effective, scalable, and context-appropriate interventions.

2. TPB variables and hypothesis development

The theory of planned behavior (TPB) is a general activation theory that explains social behavior, directing psychological determinants and intention and also acting as a domain of pro-environmental behavior (PEB) (Cheng et al. 2022). In the context of behavioral intention in reducing indoor air pollution in households, TPB constructs with three independent determinants: attitudes (AT), subjective norm (SN), and perceived behavioral control (PBC) and they vary with social and environmental context (Ajzen, 1991).

Environmental Knowledge (EK)

Environmental knowledge (EK) refers to an individual's awareness and understanding of environmental issues and their consequences (Ramsey and Rickson 1976). In the context of daily life, EK includes familiarity with common environmental challenges, such as indoor air pollution. Prior studies have demonstrated that EK significantly predicts pro-environmental behavior and positively shapes environmental attitudes (Duan and Sheng 2018; Xie and Lu 2022). Moreover, higher environmental knowledge may contribute to the initial formation of favourable environmental attitudes (Ramsey and Rickson 1976). Building on this theoretical foundation, EK is included as an extended TPB construct to assess its relationship with both attitude and behavioral intention. Accordingly, we propose our first two hypotheses (H1 and H2).

H1: Environmental knowledge (EK) is positively related to attitude (AT) toward reducing indoor air pollution
H2: Environmental knowledge (EK) is positively related to behavioral intention (BI) to reduce indoor air pollution

Attitude (AT)

According to (Ajzen, 1991), attitude refers to the degree to which a person has a favourable or unfavourable evaluation or appraisal of the behavior in question. In the context of this study, attitude refers to an individual's belief and behavioral intention of reducing indoor air pollution levels. Previous studies have confirmed that favourable attitudes are expected to increase willingness to engage in pollution-reducing behavior (Shi, Wang, and Zhao 2017a; 2017b).

H3: Attitude (AT) is positively related to behavioral intention (BI) to reduce indoor air pollution.

Subjective Norm (SN)

Subjective norms reflect the social pressure gained from significant people around them that an individual feels when performing or refraining from certain behaviors (Finlay, Trafimow, and Moroi 1999). The stronger the subjective norms perceived by the key influencers, like family and close friends, the greater the individual will feel pressure to perform a specific behavior (De Leeuw et al. 2015; Ru, Wang, and Yan 2018). In the study of Chang, (1998) the relation between subjective norms and attitudes towards a specific behavior was significant and explained by the influence of the social environment on an individual's attitude formation. In the same way, expectations of surrounding people like family and friends concerning indoor air pollution reductions may have some effects on household air pollution reduction activities (Ajzen 1991). Thus, we can propose the hypothesis that:

H4: Subjective norm (SN) is positively related to attitude (AT) toward reducing indoor air pollution.

Paul et al., (2016) found that subjective norms directly affect PBC. PBC reflects past experiences and anticipated challenges, including the perspective of surrounding people towards the behavior. Several past studies discussed modifying the effect of subjective norms on PBC in different contexts, such as behavior against $PM_{2.5}$ (Liu et al., 2018), organic food purchasing(Al-Swidi and Saleh 2021), and healthy eating (Povey et al. 2000).Thus, it can be hypothesized that:

H5: SN is positively related to PBC toward reducing indoor air pollution.

H6: SN is positively related to behavioral intention (BI) to reduce indoor air pollution.

Perceived Behavioral Control (PBC)

Perceived behavioral control (PBC) refers to an individual's perceived ease or difficulty in performing a specific behavior, reflecting both internal and external constraints (Ajzen, 1991; Ajzen and Fisbbein, 1974). In the household context, PBC may relate to financial costs, time availability, or access to resources for improving indoor air quality. A higher level of PBC has been shown to predict stronger behavioral intentions in various environmental domains, such as reducing $PM_{2.5}$ exposure (Ru et al., 2019; Shi et al., 2017a), using public transport (Bamberg, Hunecke, and Blöbaum 2007), and engaging in protective health behaviors (Liu et al., 2018; Woo et al., 2022). Following the factual evidence, our hypothesis no. 7 (H7) can be followed as:
H7: PBC is positively related to behavioral intention (BI) to reduce indoor air pollution.

Environmental Concern (EC)

Environmental concern (EC), a sub-set of environmental attitudes, can be defined as the emotional responses and attitudes toward environmental problems (Takács-Sánta 2007). The Environmental Paradigm Scale (Dunlap and Van Liere 1978) and the Ecological Attitude Scale (Maloney and Ward 1973) are the two most commonly used instruments for measuring EC. A meta-analysis showed that EC has a positive relation with on both public and private pro-environmental behavior (Lou and Li 2023). Studies also showed that the $PM_{2.5}$ reduction intention has a significant indirect-positive correlation with EC (Shi et al., 2017a, 2017b). So, we developed the following hypothesis as

H8: EC is positively related to behavioral intention (BI) to reduce indoor air pollution.

Actual Behavior (AB)

Individuals' actual behavior demonstrates a strong positive correlation with their intentions across various scenarios and aspects (Fishbein 1981; Manstead, Proffitt, and Smart 1983; Ajzen and Fisbbein 1974). When a person identifies a behavior as beneficial and notices substantial positive results from it, their future actions are more likely to be shaped by that behavior. Some theorists (Bentler and Speckart 1979; Fredricks and Dossett 1983) suggest that prior behavior was associated with subsequent actions. Studies found that reducing indoor smoking, minimizing use of solid fuels for cooking, and ensuring proper ventilation can be effective in reducing air pollution (Fakhri et al. 2024; Ferdous et al. 2022; Xia et al. 2024). Based on the above discussion, we concluded our hypothesis 9 (H9) as:

H9: AB is positively related to behavioral intention (BI) to reduce indoor air pollution.

Moderating effect of PBC components

According to Ajzen and Fisbbein (1974), the relative associations among attitude (AT), subjective norm (SN), and perceived behavioral control (PBC)—the core constructs of the Theory of Planned Behavior (TPB)—may vary depending on specific behaviors and contextual factors. In general, previous studies have observed that more favourable perceptions of PBC tend to correspond with stronger associations between AT, SN, and individuals' behavioral intentions (De Leeuw et al., 2015; Ru et al., 2019; Shi et al., 2017b). PBC is often informed by individuals' prior experiences and anticipated challenges, as well as by the perceived expectations of others. While PBC is frequently found to be directly associated with behavioral intention (BI), evidence also suggests that the strength of relationships between AT, SN, and BI may differ depending on the level of PBC. This implies that PBC may play a moderating role, whereby variations in perceived control could shape how attitudinal and normative factors relate to pro-environmental behavioral tendencies. Following this, our H10 and H11 can be:

H10: PBC positively moderates SN, which is associated with behavioral intention (BI) to reduce indoor air pollution.

H11: PBC positively moderates AT which is associated with behavioral intention (BI) to reduce indoor air pollution.
As a result, the conceptual framework of this study is illustrated in Figure 1.

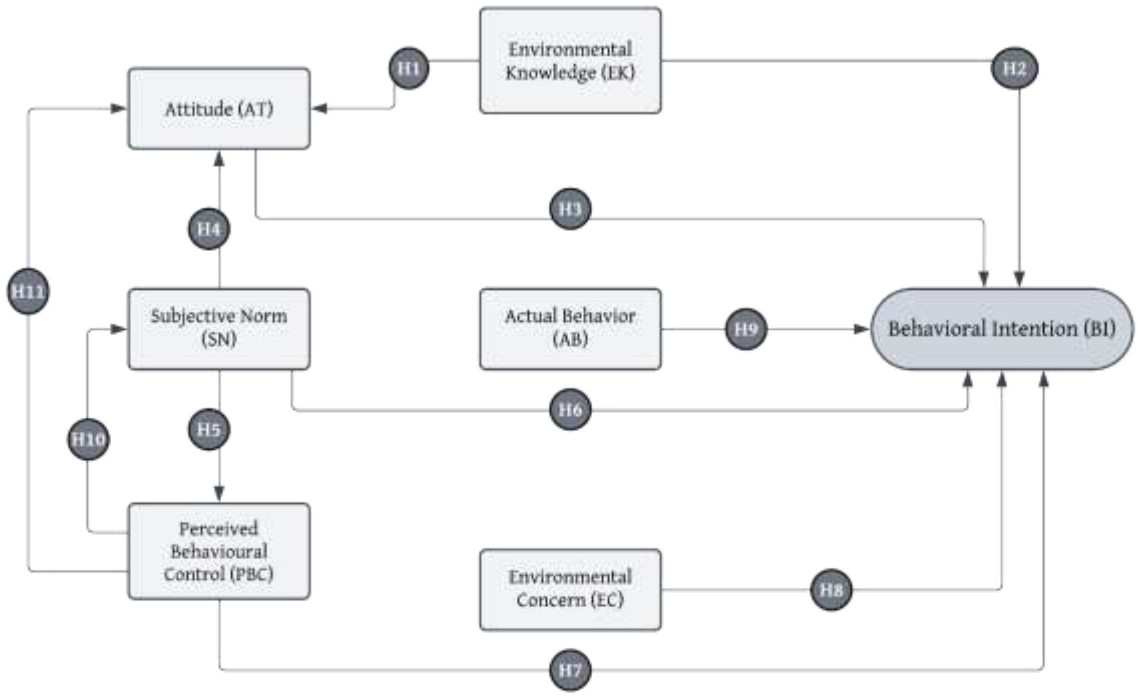

Figure 1 Conceptual framework of the study

3. Methods

3.1 Study area

The study was conducted in Bangladesh, a lower-middle-income country located in South Asia. Administratively, Bangladesh is divided into eight divisions—Dhaka, Chattogram, Khulna, Rajshahi, Sylhet, Barishal, Rangpur, and Mymensingh—comprising a total of 64 districts. The country's population was approximately 169.83 million in 2022, with a population density of 1,119 people per square kilometre (Population and Housing Census 2022). The number of households has increased significantly, reaching 41,010,051 in 2022. Urban districts such as Dhaka, Savar, Narayanganj, Narsingdi, Gazipur, Chattogram, and Khulna are prominent industrial and commercial hubs, and they experience high levels of air pollution. Dhaka, the capital city, consistently ranks among the most polluted cities globally, with an average $PM_{2.5}$ concentration of 79.9 $\mu g/m^3$—far exceeding the World Health Organization's recommended limits (IQAir 2024). Moreover, rapid urbanization, coal-based fuel usage, poor ventilation systems, and high population density further elevate the health risks in these areas (Hassan, Bhuiyan, and Rahman 2023; Lipi and Hasan 2021; Siddiqui et al. 2020).

3.2 Sampling and data collection

This study employed a cross-sectional research design with a quantitative approach to examine the behavioral intentions of urban residents in Bangladesh toward reducing indoor air pollution, based on constructs from the extended Theory of Planned Behavior (TPB). The target population included adults aged 18 and above from various regions such as Dhaka, Chattogram, Khulna, Bogura, Rajshahi, Cox's Bazar, and Gazipur. Data were collected through a self-reported structured online questionnaire consisting of 35 items, translated into Bengali to ensure comprehension, and distributed via social media platforms including Facebook Messenger, WhatsApp, and LinkedIn using a convenience sampling method. Prior to the main data collection, a pre-test was conducted among a small group of participants to identify any limitations in the questionnaire and to evaluate its suitability. Based on the feedback, minor revisions were made to the wording and structure of selected questions to improve clarity and ensure cultural sensitivity. The full survey was administered between March and June 2024. Using the Qualtrics online sample size calculator (Qualtrics 2023) and assuming a 95% confidence level with a 5% margin of error, the minimum required sample size was calculated to be 385. In total, 614 responses were received. After excluding duplicate entries and submissions from households without kitchen facilities, 410 valid responses from urban participants were retained for final analysis—surpassing the required sample size and enhancing the statistical reliability of the study findings.

3.3 Ethical consideration

Following the principles stated in the "Declaration of Helsinki," the questionnaire clearly explained the purpose of the study, and participation was entirely voluntary. Informed consent was obtained from all participants before beginning the survey. Participants were also informed that they could opt out at any point without any consequences. No personally identifiable information was collected, ensuring anonymity and confidentiality throughout the process.

3.4 Measurement instruments

The questionnaire used in this study was developed based on the proposed research framework and organized into three main sections: demographic information, behavioral intention to reduce indoor air pollution, and influencing factors derived from the Theory of Planned Behavior (TPB) and its extended constructs. The dependent variable in this study was behavioral intention (BI), measured through four items reflecting participants' willingness to engage in practices aimed at reducing indoor air pollutions. Independent variables included the three core TPB constructs—attitude (AT), subjective norm (SN), and perceived behavioral control (PBC)—as well as extended variables: environmental knowledge (EK), environmental concern (EC), and actual behavior (AB). The demographic variables, including location, residence type, sex, age, education, monthly income, occupation, kitchen location, cooking fuel type, and ventilation system, were treated as covariates to explore their potential association with BI. Except for the demographic and actual behavior sections, all constructs were measured using a 5-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree," while AB was assessed using a frequency scale from "Never" to "Always." Items for TPB constructs were adapted from validated scales used in prior studies to ensure conceptual alignment and measurement reliability mentioned in Table 1.

Table 1 Measurement items

Constructs	Item no	Questions	Sources
Attitude (AT)	3	Participating in indoor air pollution reduction behavior for households improves air quality.	(Ajzen, 1991; Liu et al., 2018; Shi et al., 2017a)
		I believe that using products (e.g. cooking fuel, candles, kerosene, smoking, aerosols, cosmetic products) that generate harmful air pollutants like $PM_{2.5}$ and PM_{10} is not good for human health.	
		If there is any alternative product (e.g. LPG as a cooking fuel, electric mosquito repellent) that will generate less pollutants, I will switch to that	

		alternative product even if it costs more.	
Subjective norm (SN)	3	My family encourages me to participate in indoor air pollution reduction behavior.	(Kaiser and Kibbe 2017; Weng et al. 2021)
		My friends also encourage me to participate in indoor air pollution reduction behavior.	
		People who are important to me (except my family and friends) expect me to reduce activities that increase indoor air pollution.	
Perceived Control Behavior (PBC)	4	I feel better that I can control the sources that generate indoor air pollution in households.	(Ajzen, 1991; Sarkodie et al., 2019; Shi et al., 2017a; Woo et al., 2022)
		I feel financially capable of choosing less pollutant-emitting products that encourage me to participate in indoor air pollution reduction behavior.	
		I have enough time and opportunities to participate in indoor air pollution reduction behavior.	
		It is entirely up to me if I want to participate in indoor air pollution reduction behavior.	
Environmental Knowledge (EK)	3	Harmful pollutants in indoor like $PM_{2.5}$, PM_{10}, can be generated from cooking fuel, candles, kerosene, smoking, aerosols, cosmetic products, and burning mosquito-repellent incense.	(Daniel et al., 2020; Khalequzzaman et al., 2010; Kurata et al., 2020; Wang et al., 2018)
		Air pollutants like $PM_{2.5}$ can easily penetrate into the human body, affecting respiratory diseases, along with cardiovascular diseases.	
		Indoor air pollutants (e.g., $PM_{2.5}$) can be responsible for respiratory infections, including pneumonia, lung cancer, stroke and cardiovascular diseases, especially in children and elderly residents.	
Environmental Concern (EC)	3	I am worried about indoor air pollution that may occur in my house.	(Kaiser and Kibbe, 2017; Park et al., 2022; Weng et al., 2021)
		Indoor plants can be beneficial in reducing indoor air pollution.	
		I believe that better awareness and responsibility can lead to sustainable environmental practice and behavior.	
Actual Behavior (AB)	5	I have not smoked inside my house for the last two years.	(Ajzen, 1991; Liu et al., 2018)
		In the past two years, I avoided or altered harmful cosmetic products (e.g. hair dryer, hair spray, nail polish) or cleaning products (e.g. shoe products, carpet cleaners, fabric softener) that are likely to emit more harmful emissions like $PM_{2.5}$ and PM_{10}.	
		In the past two years, I have tried to reduce my cooking time as it increases the exposure to indoor air pollutants.	
		I encourage my friends and family to participate in indoor air pollution reduction behavior.	

		In the past two years, I switched to or installed a proper ventilation system in my house that can reduce indoor air pollution.	
Behavioral Intention (BI)	4	I intend to participate in activities that are likely to generate fewer emissions to the indoor environment	(Liu et al., 2018; Ru et al., 2019)
		I advise my friends and family to take precautionary steps to reduce indoor air pollution.	
		I use less harmful cooking fuel in less time, even if it costs much more.	
		I plan to use an air purifier and indoor plants to improve the air quality of my house.	

3.5 Data analysis

The survey responses were first cleaned and coded in Excel, and then imported into R to perform descriptive statistics to summarize demographic and construct-level variables. Normality of data was tested using the Shapiro-Wilk test. Given the ordinal nature of most variables and the observed non-normality, Spearman's rank correlation was used to examine associations among variables.

To evaluate the hypothesized relationships, Structural Equation Modelling (SEM) was applied, which enables the simultaneous assessment of multiple direct and indirect effects between latent and observed variables. SEM is preferred in this context as it accounts for measurement error, models latent constructs with multiple observed indicators, and accommodates mediation pathways. It also offers robust solutions to potential endogeneity issues and allows assessment of both direct and indirect (mediated) relationships in a single comprehensive model (Wang et al. 2022; Cao and Yang 2017). In this study, SEM was used to test both the measurement and structural models of the extended TPB framework, including the core TPB variables (Attitude, Subjective Norm, Perceived Behavioral Control) and extended constructs (Environmental Knowledge, Environmental Concern, and Actual Behavior) predicting Behavioral Intention (BI).

Prior to SEM, multicollinearity was assessed through the Variance Inflation Factor (VIF), with all variables reporting values below the accepted threshold of 5, indicating no multicollinearity concerns. Confirmatory Factor Analysis (CFA) was performed to evaluate the reliability and validity of the latent constructs. Factor loadings (FL), Composite Reliability (CR), Average Variance Extracted (AVE), and Cronbach's Alpha (α) were computed. A factor loading threshold of >0.5 (Fornell and Larcker 1981a), CR >0.70, AVE >0.50, and α >0.70 were used to confirm internal consistency, convergent validity, and construct reliability (Cheung et al. 2023; Zahedi, Batista-Foguet, and van Wunnik 2019).

SEM was then performed using the lavaan package in R to test the hypothesized relationships within the extended TPB framework. Model fit was evaluated using multiple goodness-of-fit indices: Comparative Fit Index (CFI $\geq$ 0.90), Tucker-Lewis Index (TLI $\geq$ 0.90), Root Mean Square Error of Approximation (RMSEA $\leq$ 0.08), and Standardized Root Mean Square Residual (SRMR $\leq$ 0.08) (Hair et al. 2010). Discriminant validity was tested using Fornell and Larcker's criterion, ensuring that the square root of each construct's AVE was greater than its inter-construct correlations. Paths were considered statistically significant at $p < 0.05$. All valid responses were analysed using R (version 4.3.1) lavaan package for comprehensive statistical analysis.

4. Results
4.1. Characteristics of the respondents

More than half were male (53%), and the majority were aged 18–29 years (88%). Most participants had at least an undergraduate-level education (63%). Students made up the dominant occupational group (70%). Monthly household income varied, with most earning between 20,000–40,000 BDT (30%) or above 40,000 BDT (27%). The majority of respondents reported having a kitchen inside the house (90%) and with adequate air circulation (88%). The most commonly used cooking fuels were LPG (51%) and natural gas (44%). Table 2 summarizes the characteristics of the respondents.

Table 2 Characteristics of the respondents (n = 410)

Variable	Categories	Frequency (n)	Percentage (%)
Gender	Male	217	52.93
	Female	193	47.07
Age	18-29	362	88.3
	30-39	30	7.32
	40-49	13	3.17
	50-59	5	1.22
	above 60	0	0
Education	No formal education	3	0.73
	Below college	13	3.17
	College	69	16.83
	Undergraduate	259	63.17
	Post Graduate or above	66	16.1
	Prefer not to say	0	0
Occupation	Unemployed	37	9.03
	Student	287	70
	Employed	67	16.4
	Housewife	19	4.6
Income	Below 10000	84	20.49
	10000-20000	94	22.93
	20000-40000	121	29.51
	Above 40000	111	27.07
Kitchen Location	Inside the house	368	89.76
	Outside the house	42	10.24
Kitchen air circulation Facility	Yes	362	88.29
	No	48	11.71
Kitchen Fuel	Natural gas	179	43.66
	LPG	208	50.73
	Biomass	5	1.22
	Kerosine	2	0.49
	Koyla	0	0

	Charcoal	0	0
	Wood	48	11.71
	Garbage	10	2.44
	Electrical tools	85	20.73
	Not applicable	3	0.73

4.2. Measurement model

All constructs demonstrated satisfactory reliability, with Cronbach's alpha values ranging from 0.78 to 0.90, exceeding the recommended threshold of 0.70. Composite reliability values also met the acceptable standard, ranging from 0.72 to 0.90, confirming strong internal consistency across all constructs. Convergent validity was assessed using standardized factor loadings and Average Variance Extracted (AVE). All item loadings ranged from 0.66 to 0.93, surpassing the minimum loading requirement of 0.50, indicating strong indicator reliability. The AVE values ranged from 0.46 to 0.75. Although the AVE for the construct "Attitude" fell slightly below the 0.50 thresholds (0.462), its composite reliability was above 0.70, suggesting that convergent validity remained acceptable (Fornell and Larcker 1981b). Discriminant validity was evaluated using the Fornell–Larcker criterion. The square root of the AVE for each latent construct was greater than its correlations with other constructs, indicating that the constructs were empirically distinct and supporting discriminant validity (Paulraj, Lado, and Chen 2008). The result of the confirmatory factor analysis and discriminant validity is summarized in Table 3. Fit indices for the measurement model further supported the adequacy of the model: χ^2 = 741.39, RMSEA = 0.077 (< 0.08), CFI = 0.904 (> 0.90), TLI = 0.887 (> 0.90), and SRMR = 0.060 (< 0.08).

Table 3 Results of the confirmatory factor analysis and discriminant validity

		Confirmatory factor analysis						Discriminant validity						
Constructs		**Mean**	**SD**[1]	**Standardized loading**	**Cronbach's alpha**	**Composite Reliability**	**AVE**[2]	**EK**[3]	**AT**[4]	**SN**[5]	**PBC**[6]	**EC**[7]	**AB**[8]	**BI**[9]
EK	EK1	3.95	0.98	0.81	0.84	0.90	0.75	**0.87**						
	EK2	4.19	1.00	0.93										
	EK3	4.05	1.03	0.86										
AT	AT1	3.58	0.95	0.59	0.82	0.72	0.46	0.57	**0.68**					
	AT2	4.02	0.88	0.79										
	AT3	3.70	1.00	0.66										
SN	SN1	3.68	0.96	0.79	0.83	0.83	0.63	0.33	0.48	**0.79**				
	SN2	3.37	1.03	0.78										
	SN3	3.54	1.01	0.80										
PBC	PBC1	4.01	0.97	0.82	0.81	0.81	0.53	0.45	0.56	0.57	**0.73**			
	PBC2	3.63	1.02	0.76										
	PBC3	3.51	1.03	0.69										
	PBC4	3.82	1.03	0.65										
EC	EC1	3.79	0.98	0.69	0.83	0.82	0.60	0.45	0.43	0.35	0.52	**0.78**		
	EC2	3.99	0.92	0.76										
	EC3	4.19	0.88	0.89										
AB	AB3	3.24	1.36	0.67	0.78	0.78	0.54	0.12	0.12	0.40	0.29	0.16	**0.74**	
	AB4	3.55	1.37	0.84										
	AB5	3.63	1.34	0.69										
BI	BI1	4.05	0.96	0.81	0.82	0.87	0.63	0.41	0.41	0.49	0.61	0.60	0.30	**0.79**
	BI2	3.85	0.97	0.85										
	BI3	3.72	1.05	0.80										
	BI4	3.80	1.02	0.71										

[1] SD= Standard Deviation
[2] AVE= Average Variance Extracted
[3] EK= Environmental Knowledge
[4] AT = Attitude
[5] SN= Subjective Norm
[6] PBC= Perceived Behavioral Control
[7] EC= Environmental Concern
[8] AB= Actual Behavior
[9] BI= Behavioral Intention

4.3. Hypothesis testing

To examine the hypothesized relationships among the constructs, the structural model was tested using Structural Equation Modelling (SEM). The results are presented in Table 4 and Figure 2. Several hypothesized paths were found to be statistically significant, offering empirical support for our conceptual framework. Consistent with H1, environmental knowledge (EK) demonstrated a significant positive association with attitude (AT) ($\beta = 0.787$, $p < 0.001$), indicating that individuals with greater environmental awareness tend to hold more favourable attitudes toward reducing indoor air pollution. However, the direct path from EK to behavioral intention (BI) was not statistically significant ($\beta = -0.125$, $p = 0.345$), leading to the rejection of H2. The third hypothesis (H3) was supported, as AT showed a strong positive effect on BI ($\beta = 0.836$, $p < 0.001$), suggesting that individuals with positive attitudes are more likely to form BI to reduce indoor air pollution. In contrast, H4 was not supported, as SN did not significantly relate to AT ($\beta = -0.080$, $p = 0.545$). However, SN had a strong positive relation with PBC ($\beta = 0.803$, $p < 0.001$), supporting H5, and also directly related to BI ($\beta = 0.430$, $p < 0.001$), supporting H6. Further, PBC was significantly associated with BI ($\beta = 0.334$, $p = 0.004$), validating H7 and emphasizing the importance of individuals' confidence in their ability to perform pollution-reducing actions. As expected, EC is also positively related to BI ($\beta = 0.661$, $p < 0.001$), offering strong support for H8 and suggesting that individuals with higher concern for the environment are more inclined to adopt pro-environmental behavior. Finally, H9 was supported, as AB showed a significant and strong association with BI ($\beta = 0.832$, $p < 0.001$), implying that higher behavioral intention is reflected in real-world action.

Table 4 Hypothesis testing by Structural Equation Modelling (SEM)

Path	**Relationship**	**Estimate**	**β**	**Standard Error**	**t value**	**P-value**	**Supported (if p <0.05)**
H1	EK~ AT	0.563	0.787	0.071	7.939	0.000	Yes
H2	EK~ BI	-0.120	-0.125	0.128	-0.943	0.345	No
H3	AT~ BI	0.810	0.836	0.074	10.963	0.000	Yes
H4	SN~ AT	-0.080	-0.080	0.133	-0.605	0.545	No
H5	SN~ PBC	0.690	0.803	0.066	10.541	0.000	Yes
H6	SN~ BI	0.498	0.430	0.077	6.494	0.000	Yes
H7	PBC~ BI	0.451	0.334	0.155	2.903	0.004	Yes
H8	EC~ BI	0.659	0.661	0.130	5.072	0.000	Yes
H9	AB~ BI	1.162	0.832	0.231	5.025	0.000	Yes

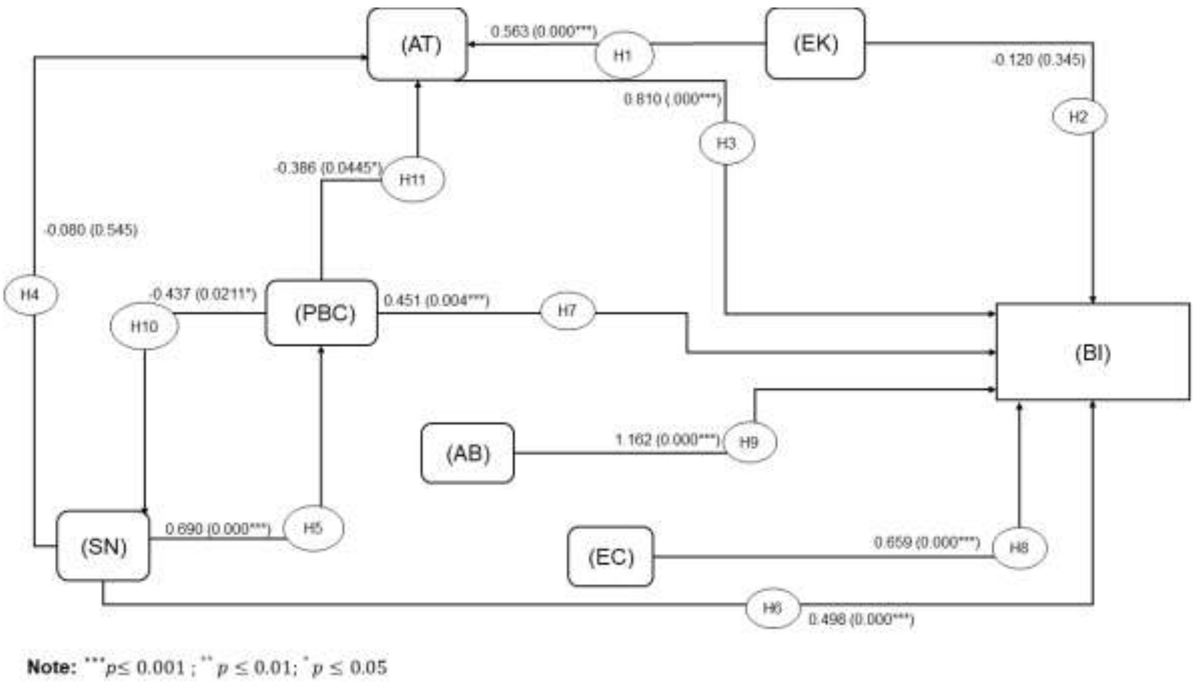

Figure 2 Path diagram of the SEM used in the main analysis

4.4. Moderating effect testing

Given the rejection of H4 in SEM, which hypothesized a direct relationship between subjective norm (SN) and attitude (AT), we further investigated whether PBC moderated key relationships within the TPB framework. Specifically, we examined the moderating effect of PBC on (i) the relationship between AT and BI, and (ii) the relationship between SN and BI. Moderation was tested using the product-indicator approach (Chin et al., 2003; Shi et al., 2017a), wherein all relevant variables were standardized prior to interaction term computation. To further examine the moderation effect, we categorized PBC into two groups representing high and low PBC. We plotted the regression lines separately to understand the relationship between AT and SN on BI under two different graphs (Figure 3 & 4).

The first moderation model examined whether PBC was associated with variation in the relationship between AT and BI. The interaction term (AT × PBC) was statistically significant ($\beta = -0.386$, $p = 0.0445$), suggesting that PBC may moderate the strength of the association between AT and BI (Table 5). The model accounted for 25.54% of the variance in BI ($R^2 = 0.2554$), with a residual standard error (RSE) of 0.8661. As illustrated in Figure 3, under lower levels of PBC (blue line), the relationship between AT and BI appeared stronger. In contrast, at higher levels of PBC (red line), the association between AT and BI was less pronounced.

Table 5 Moderation effect analysis of PBC on AT and BI relationship

	Estimate	**Std. error**	**T value**	**Pr (> |t|)**
Intercept	0.50056	0.06826	7.333	0.001***
AT	-0.3118	0.14359	-2.172	0.03
PBC	-0.50146	0.12164	-4.123	0.001***
AT: PBC	-0.3857	0.19135	-2.016	0.0445*
Residual Std. Error (RSE) = 0.8661, Degree of freedom = 406; Multiple R^2 = 0.2554				

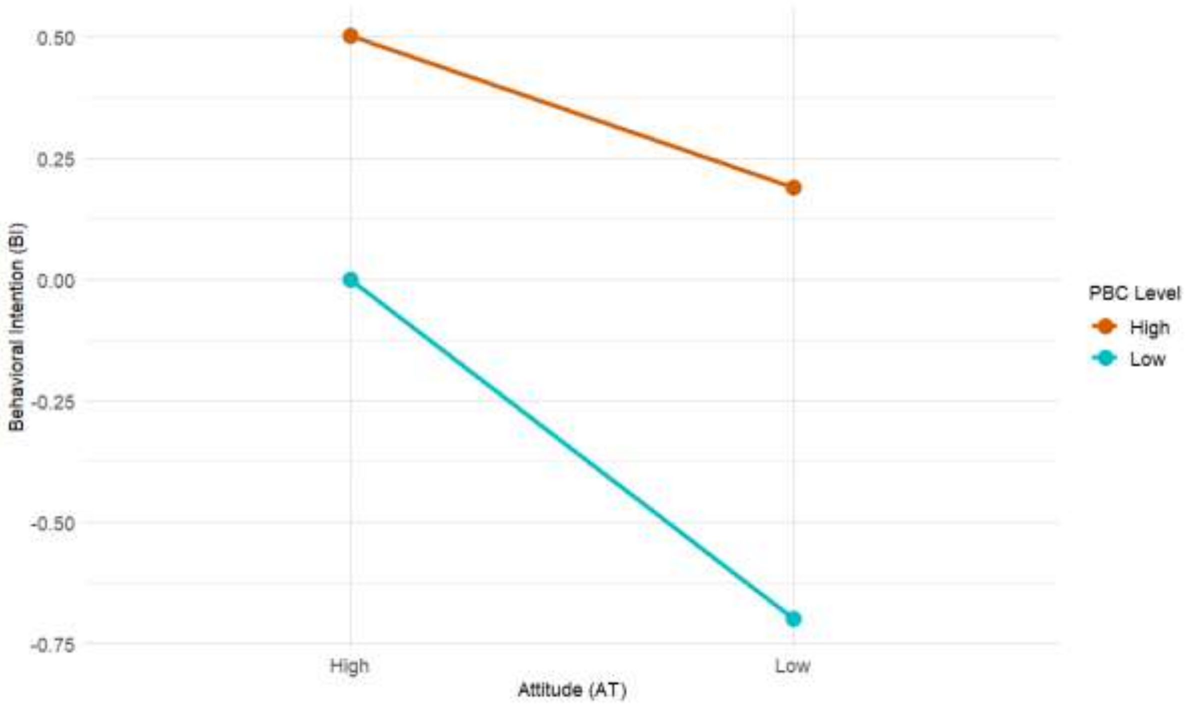

Figure 3 The moderating effect of PBC on AT and BI relationship

The second model explored whether PBC was associated with variation in the relationship between SN and BI. The interaction term between SN and PBC was statistically significant (β = –0.437, p = 0.0212), suggesting that PBC may moderate this association (Table 6). This model explained approximately 25.86% of the variance in BI (R^2 = 0.2586), with a residual standard error (RSE) of 0.8642. The interaction plot (Figure 4) further illustrates this pattern. When PBC was lower (orange line), the relationship between SN and BI appeared stronger. Conversely, under conditions of higher PBC (blue line), the association between SN and BI appeared weaker.

Table 6 Moderation effect analysis of PBC on SN and BI relationship

	Estimate	**Std. error**	**t value**	**Pr (> |t|)**
(Intercept)	0.501	0.068	7.271	0.001***
SN	-0.291	0.139	-2.09	0.0372*
PBC	-0.472	0.123	-3.821	0.001***
SN: PBC	-0.436	0.188	-2.314	0.021*
Residual Std. Error (RSE) = 0.8642, Degree of freedom = 406; Multiple R^2 = 0.2586				

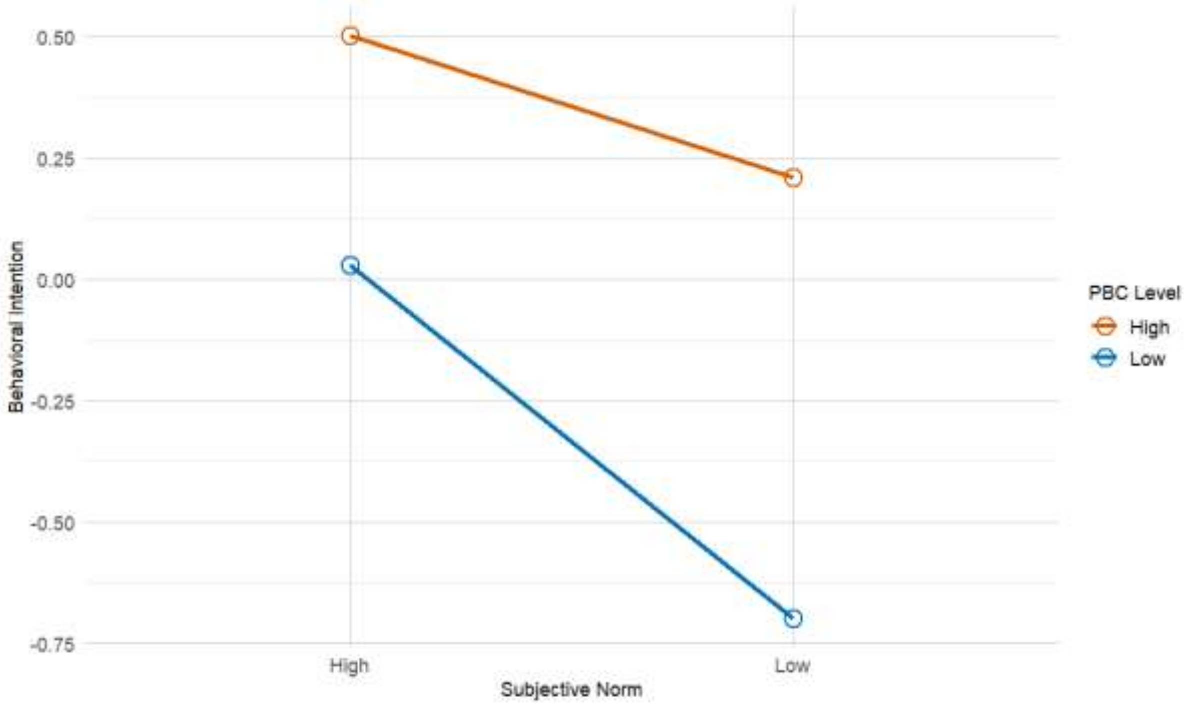

Figure 4 The moderating effect of PBC on SN and BI relationship

5. Discussion

This study examined the determinants of households' behavioral intentions (BI) to mitigate indoor air pollution, employing an extended Theory of Planned Behavior (TPB) framework. Specifically, we assessed the association of Attitude (AT), Perceived Behavioral Control (PBC), Subjective Norm (SN), Environmental Concern (EC), Environmental Knowledge (EK), and Actual Behavior (AB) with BI. While much of the existing literature focuses on ambient or outdoor air pollution, this study contributes to the relatively underexplored domain of household-level indoor air pollution and the psychosocial drivers of behavioral change. Our results demonstrated a significant positive relation of AT, SN, PBC, EC, and AB with BI, whereas PBC moderated the effects of AT and SN on BI. Structural Equation Modelling (SEM) and Confirmatory Factor Analysis (CFA) confirmed the robustness and excellent fit of the extended TPB framework with our data. The study offers valuable theoretical insights and practical policy implications to design targeted interventions that promote sustainable indoor air pollution reduction behaviors among urban residents.

5.1. Evaluation of the main findings

Our empirical study verified that individuals' attitude (AT) has a significantly positive association with behavioral intentions to participate in reducing indoor air pollution. Similar findings from previous studies also confirm the positive role of AT in individuals' behavior towards pollution reduction (Park et al., 2022; Ru et al., 2019; Shi et al., 2017a). Although AT is the strongest factor among all TPB elements in explaining individuals' behavioral intentions (Shi et al., 2017a) our study suggests that environmental knowledge (EK) is positively related to individuals' AT towards pro-environmental behavior in reducing indoor air pollution. A study in Italy suggests that individuals who possess more knowledge often make more informed consumer decisions, like they are more likely to purchase plants that help to enhance air quality, pay more attention to the particular features of items instead of depending on habitual decisions (Venuto et al. 2024). However, the mean EK score (M = 4.06) and mean AT score (M = 3.77) suggest that even if people have a moderate to higher level of knowledge, it does not reflect the same as their attitudes towards pollution reduction. Thus, along with individuals' increased knowledge of the direct effects of indoor air pollution exposure, government and policymakers must create scope and provide incentives to overcome the knowledge-practice gap in pro-environmental behaviors towards indoor air pollution.

Our study found that subjective norms (SN) were positively related to individuals' intention to engage in indoor pollution reduction behavior. This finding aligns with previous research that emphasizes the role of SN in shaping environmental behaviors (Blok et al., 2015; Ru et al., 2019; Shi et al., 2017b). Further, the mean score of SN (M = 3.51) suggests that individuals perceive a moderate level of social support for these behaviors, reinforcing the idea that social norms may associate with individuals to engage in pro-environmental actions (Gifford and Nilsson 2014). Moreover, our study found a positive relationship between SN and Perceived Behavioral Control (PBC), indicating that social support and encouragement from family, friends or important people, when combined with a sense of control over one's actions, significantly enhance the likelihood of engaging in behaviors aimed at reducing air pollution. This aligns with earlier studies that emphasize the importance of both social influence and perceived behavior control in motivating pro-environmental behaviors (Ru et al., 2019). In Bangladesh, where social and community ties are strong, individuals often look to family members, community leaders, and religious figures when making decisions about environmental actions (Azad et al. 2019). Therefore, government interventions should focus on leveraging community-based programs and policy initiatives that reinforce positive social norms. Awareness campaigns led by local leaders, religious institutions, and media can amplify the visibility of sustainable behaviors, making them more socially desirable (Shi et al., 2017a).

Our findings found that perceived behavioral control (PBC) was positively related to individuals' intention to participate in reducing household air pollution. This is consistent with previous studies, which suggest that those with greater control over their actions are more likely to adopt pollution-mitigating behaviors, such as using cleaner cooking fuels or improving ventilation (Wyss, Knoch, and Berger 2022; Carlsten et al. 2020). Interventions that increase perceived ease of using air pollution control measures have also led to higher adoption rates (Shi et al., 2017a; Woo et al., 2022, 2023). However, as indicated by the mean PBC score (M = 3.74), many individuals face constraints such as financial limitations, lack of resources, and insufficient knowledge, which hinder their ability to adopt sustainable behaviors. Given the altruistic nature of indoor air pollution reduction, government interventions are crucial in enhancing PBC. Policies should focus on infrastructure improvements, financial incentives, and awareness campaigns to empower individuals with more control over their environmental actions. For example, subsidized access to clean cooking technologies and community-based interventions could make sustainable behaviors more accessible (Kumar and Igdalsky 2019). Policymakers could leverage social norms by promoting collective action and community engagement programs to strengthen perceived control and support a culture of sustainability.

In our study, environmental concern (EC) was positively related to the individuals' behavioral intentions to participate in reducing indoor air pollution. Consistent with previous studies (Saphores, Ogunseitan, and Shapiro 2012; Chen and Tung 2014). Individuals with higher levels of environmental concern demonstrated greater motivation to engage in indoor air pollution reduction behaviors. However, the mean EC score (M = 3.99) suggests that while individuals express moderate to high concern about the environment, this concern does not always translate into actual behavior. Barriers such as cost, time, and the perceived effectiveness of individual actions can significantly reduce the likelihood of engagement in environmentally friendly behaviors (Kollmuss and Agyeman 2002; Dioba et al. 2024). The findings suggest that raising environmental concern alone is insufficient for ensuring pro-environmental actions. The government and policymakers must provide supportive infrastructure and incentives to facilitate such behaviors. For example, awareness campaigns and educational programs that promote the health impacts of indoor air pollutants could help to strengthen the risk perception associated with air pollution. Public information about the direct consequences of exposure to indoor air pollutants, coupled with strategies to overcome behavioral barriers, could enhance both motivation and action (Ramírez et al. 2019).

Actual behavior (AB) was positively related to individuals' engagement in indoor air pollution reduction behavior. Several previous studies have also confirmed that past behavior may be associated with the individuals' environmentally responsible behavioral intentions (Knussen et al. 2004; Hu et al. 2019). This indicates that individuals with a history of engaging in pollution-reducing actions are more likely to continue such behaviors in the future. However, the moderate levels of actual behavior observed (M = 3.47) indicate that, while individuals acknowledge the importance of indoor air pollution reduction—such as reducing indoor pollution sources, improving ventilation, and using air purification technologies—financial constraints, limited access to cleaner technologies, and perceived inconvenience often limit their ability to take action (Kollmuss and Agyeman 2002; Dioba et al. 2024). The government should implement targeted interventions such as financial subsidies for clean energy solutions, public awareness campaigns on indoor air pollution risks, and stricter indoor air quality regulations while also providing incentives for households to adopt cleaner cooking fuels, improve ventilation, and integrate air filtration technologies. Moreover, embedding air pollution education into public health programs and promoting community-led initiatives can further encourage individuals to adopt and sustain pollution-reducing behaviors. As individuals gain more experience with such actions, their willingness to engage in sustainable indoor air practices will increase, fostering long-term behavioral change.

Our moderation effect findings emphasize the important roles of PBC on AT and SN in forming behavioral intentions. It shows that PBC serves not only as a direct predictor of BI but also enhances or diminishes the relation of other predictors like AT and SN. For instance, we found a significant positive moderation effect of PBC on AT. It indicates that when PBC was low, the impact of AT on BI weakened (e.g., intention to reduce the use of harmful products that generate pollutants or prohibit smoking indoors or intention to use an improved air purifier or ventilation system). It suggests that individuals with fewer barriers feel more capable of acting on their attitudes to reduce indoor air pollution. The strong negative moderation of SN and PBC shows that SN's relation with BI decreases with higher PBC. Aligning with previous studies, it indicates that individuals with higher perceived control over their actions are less associated with the societal expectations while engaging in indoor pollution reduction behaviors. Similarly, when the PBC is low, individuals rely more on SN, implying seeking for social support or peer behavior to play a compensatory role in guiding their behavioral intention. Aligning with our findings, previous also suggest that PBC has a significant impact on both AT and SN, which in turn moderates BI (Ru et al., 2019; Shi et al., 2017a). Moreover, in urban Bangladesh, our study reveals that individuals with lower perceptions of control may struggle to translate their positive attitudes into intentions when they face barriers like economic or infrastructural. This finding aligns with previous research highlighting the crucial role of PBC in connecting AT, and BI (Pan et al. 2023; Liu et al. 2018a; Shi, Fan, and Zhao 2017). Furthermore, earlier studies suggest that efforts to enhance PBC—such as, providing essential resources like cleaner technologies and skills training, raising public awareness and reducing perceived external barriers—may reduce social pressure which can later strengthen sustainable behavioral intention to reduce indoor air pollution (Adewoyin, Wesson, and Vogts 2024).

5.2. Implications of the study

Previous relevant research works highlight a significant opportunity for mitigating indoor air pollution by focusing on household practices and behaviors (Kureshi et al. 2023; McCarron et al. 2022). Based on our findings, our study carries out scientific evidence by discussing the behavioral intention of indoor air pollution in urban cities of Bangladesh. With the help of the extended theory of planned behavior (TPB). Our study offers novel and detailed insights into how certain context shapes urban individuals' intention to reduce indoor air pollution. Particularly, our analysis highlights the importance of educating and empowering individuals with knowledge. It can contribute to understanding effective, tailored behavioral solutions for an LMIC like Bangladesh, where structural and technological barriers persist very strongly. As a result, we recommend focusing on the need for targeted public awareness and behavior-based intervention for policymakers to promote meaningful change in the future. Effective education and knowledge are also important to implement effective strategies for cleaner air and a healthier environment to reduce indoor air pollution. In terms of practical strategies and recommendations, we propose initiatives like transferring to cleaner fuels, improving ventilation systems, educating primary caregivers and eliminating indoor smoking to encourage households to adopt healthier practices, ultimately contributing to improved indoor air quality. Our findings may also enhance behavior-oriented policy formulation by pinpointing intervention strategies, such as community-driven campaigns that utilize social norms to encourage the adoption of cleaner cooking technologies (e.g., biogas or electric stoves) and improved ventilation practices, as evidenced in comparable low-income urban settings (Clark et al. 2013; Jeuland, Tan Soo, and Shindell 2018). The findings support the incorporation of behavioral insights into infrastructure policies for sustainable urban planning, including subsidized housing with enhanced ventilation systems and decentralized renewable energy grids to promote equitable development objectives (Ezzati and Kammen 2002; Puzzolo et al. 2016).

5.3. Limitations of the study

We understand the necessity to recognize the limitations of our current research, along with the potential opportunities for future investigations. Firstly, our study was a cross-sectional study, meaning our data collection took place at a certain time only. This design limits our ability to assess how the relationships observed among the participants may evolve or change over time. For a better and more comprehensive understanding, a longitudinal study will be more helpful in validating the stability of this relationship with time. Secondly, our survey was conducted online, so, there is a potential risk of technological and self-reporting bias. Thirdly, we did not focus on any particular age group or gender group, which may provide interesting findings in the future. Consequently, by concentrating on particular demographic segments, such as children, adolescents, or older adults, there might be some distinct patterns and insights that we have not included in our research. Future studies that address these age and gender-related differences, focusing on factors like types of kitchen ventilation, level of environmental education, subjective norm, past behavior, and perceived health risk, could provide valuable information and enhance our understanding of the topic at hand to make better policy implications in the future.

6. Conclusion

Our study investigated the determinants of indoor air pollution reduction behaviors among urban residents in Bangladesh using an extended TPB model. Specifically, our empirical study demonstrates that AT, SN, PBC, EC, and AB are directly related to behavioral intentions to reduce household air pollution following the SEM analysis. Further, PBC moderates the relation of AT and SN on behavioral intention, highlighting the significant role of self-efficacy in empowering individuals to adopt pro-environmental actions regardless of social pressures or attitudes. It indicates that some may feel or possess a positive attitude and strong social support with subjective norms, yet they feel incapable due to low perceived control. Alongside the direct relations, these moderating effects are particularly noteworthy as they may contribute to the pro-environmental behavior of individuals’ intention to reduce indoor air pollution. At the individual level, we propose initiatives to discourage indoor smoking and promote alternatives to mosquito repellents and burning candles, such as using low-cost lighting and electric devices. Beyond these alternatives, we must also be well informed about specific pollutants to ensure our safety. Finally, it is important to pay attention to all determinants while formulating policies. In this context, the government can take the initiative to include behavioral determinants in public health programs and education, which will encourage community involvement by implementing effective environmental education and awareness programs. Moreover, practical solutions, financial subsidies for clean energy, and awareness campaigns promoting sustainable behaviors are essential for improving indoor air quality, alongside incentives for cleaner cooking fuels, better ventilation, and air filtration technologies. Moreover, with Bangladesh's alarming rise in indoor air pollution, this study can inform policy implications and provide recommendations based on our empirical findings to foster pro-environmental behavior in Bangladesh.

Funding

No funding was received for conducting this study.

Disclosure Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The author confirms that all data generated or analyzed in this study are included in the manuscript. Furthermore, the primary sources and the data supporting the findings of this study will be available upon request

References

Acheampong, Ransford A. 2017. “Towards Sustainable Urban Transportation in Ghana: Exploring Adults’ Intention to Adopt Cycling to Work Using Theory of Planned Behaviour and Structural Equation Modelling.” *Transportation in Developing Economies* 3 (2). https://doi.org/10.1007/s40890-017-0047-8.

Adewoyin, Oluwande, Janet Wesson, and Dieter Vogts. 2024. “The PBC Model: Promoting Positive Behaviours through Change-Based Interventions.” *Cognition, Technology & Work* 26 (4): 673–708. https://doi.org/10.1007/s10111-024-00776-4.

Adili Y, Zella. 2018. “Economics of U Sing Improved Firewood Cooking Stove and Its Contribution on Climate Change Adaptation and Mitigation.” *International Journal of Environmental Sciences & Natural Resources* 14 (3). https://doi.org/10.19080/IJESNR.2018.14.555888.

Ahmad, Tusawar Iftikhar, Kokab Kiran, and Amina Alamgir. 2023. “Households’ Clean Cooking Fuel Poverty: Testing the Energy-Ladder Hypothesis in the Case of Bangladesh.” *iRASD Journal of Energy & Environment* 4 (1): 1. https://doi.org/10.52131/jee.2023.0401.0034.

Ajzen, Icek. 1991. “The Theory of Planned Behavior.” *Organizational Behavior and Human Decision Processes* 50 (2): 179–211. https://doi.org/10.1016/0749-5978(91)90020-T.

Ajzen, Icek, and Martin Fisbbein. 1974. “Factors Influencing Intentions and the Intention-Behavior Relation.” *Human Relations - HUM RELAT* 27 (January): 1–15. https://doi.org/10.1177/001872677402700101.

Akteruzzaman, Md., Md. Alinur Rahman, Fahim Muntasir Rabbi, Sohely Asharof, Mahi Muzammel Rofi, Md. Kamrul Hasan, Md. Abdul Muktadir Islam, M. Azizur R. Khan, Mohammad Mahfuzur Rahman, and Md. Hasibur Rahaman. 2023. “The Impacts of Cooking and Indoor Air Quality Assessment in the Southwestern Region of Bangladesh.” *Heliyon* 9 (1): e12852. https://doi.org/10.1016/j.heliyon.2023.e12852.

Alam, Md Badsha, Supria Acharjee, S.M. Ashique Mahmud, Jesmin Akter Tania, Md Mostaured Ali Khan, Md Syful Islam, and Md Nuruzzaman Khan. 2022. "Household Air Pollution from Cooking Fuels and Its Association with Under-Five Mortality in Bangladesh." *Clinical Epidemiology and Global Health* 17 (September): 101134. https://doi.org/10.1016/j.cegh.2022.101134.

Alexeeff, Stacey E., Noelle S. Liao, Xi Liu, Stephen K. Van Den Eeden, and Stephen Sidney. 2021. "Long-Term PM $_{2.5}$ Exposure and Risks of Ischemic Heart Disease and Stroke Events: Review and Meta-Analysis." *Journal of the American Heart Association* 10 (1): e016890. https://doi.org/10.1161/JAHA.120.016890.

Alhajeri, Nawaf S., Alanood M. Alrashidi, Mohamed F. Yassin, and Layla Al-Awadi. 2024. "Optimizing Indoor Air Quality: Investigating Particulate Matter Exposure in Household Kitchens and Source Identification." *Environmental Quality Management* 34 (1): e22198. https://doi.org/10.1002/tqem.22198.

Ali, Jabir, and Muqbil Burhan. 2024. "Factors Affecting the Adoption of Air Pollution Control Measures across Firms in India." *Journal of Cleaner Production* 474 (October): 143612. https://doi.org/10.1016/j.jclepro.2024.143612.

Al-Swidi, Abdullah, and Redhwan Mohammed Saleh. 2021. "How Green Our Future Would Be? An Investigation of the Determinants of Green Purchasing Behavior of Young Citizens in a Developing Country." *Environment, Development and Sustainability* 23 (9): 13436–13468. https://doi.org/10.1007/s10668-020-01220-z.

Amadu, Iddrisu, Abdul-Aziz Seidu, Aliu Mohammed, Eric Duku, Michael K. Miyittah, Edward Kwabena Ameyaw, John Elvis Hagan, Mohammed Hafiz Musah, and Bright Opoku Ahinkorah. 2023. "Assessing the Combined Effect of Household Cooking Fuel and Urbanicity on Acute Respiratory Symptoms among Under-Five Years in Sub-Saharan Africa." *Heliyon* 9 (6): e16546. https://doi.org/10.1016/j.heliyon.2023.e16546.

Azad, M. Abul Kalam, M. Salim Uddin, Sabrina Zaman, and Mirza Ali Ashraf. 2019. "Community-Based Disaster Management and Its Salient Features: A Policy Approach to People-Centred Risk Reduction in Bangladesh." *Asia-Pacific Journal of Rural Development* 29 (2): 135–160. https://doi.org/10.1177/1018529119898036.

Bamberg, Sebastian, Marcel Hunecke, and Anke Blöbaum. 2007. "Social Context, Personal Norms and the Use of Public Transportation: Two Field Studies." *Journal of Environmental Psychology* 27 (3): 190–203. https://doi.org/10.1016/j.jenvp.2007.04.001.

Bamberg, Sebastian, and Guido Möser. 2007. "Twenty Years after Hines, Hungerford, and Tomera: A New Meta-Analysis of Psycho-Social Determinants of pro-Environmental Behaviour." *Journal of Environmental Psychology* 27 (1): 14–25. https://doi.org/10.1016/j.jenvp.2006.12.002.

Begum, Bilkis A., Philip K. Hopke, and Andreas Markwitz. 2013. "Air Pollution by Fine Particulate Matter in Bangladesh." *Atmospheric Pollution Research* 4 (1): 75–86. https://doi.org/10.5094/APR.2013.008.

Bentler, Peter M., and George Speckart. 1979. "Models of Attitude–Behavior Relations." *Psychological Review* 86 (5): 452.

Blok, Vincent, Renate Wesselink, Oldrich Studynka, and Ron Kemp. 2015. "Encouraging Sustainability in the Workplace: A Survey on the pro-Environmental Behaviour of University Employees." *Journal of Cleaner Production* 106: 55–67. https://doi.org/10.1016/j.jclepro.2014.07.063.

Cao, Xiaoshu, and Wenyue Yang. 2017. "Examining the Effects of the Built Environment and Residential Self-Selection on Commuting Trips and the Related CO2 Emissions: An Empirical Study in Guangzhou, China." *Transportation Research Part D: Transport and Environment* 52: 480–494. https://doi.org/10.1016/j.trd.2017.02.003.

Carlsten, Christopher, Sundeep Salvi, Gary W.K. Wong, and Kian Fan Chung. 2020. “Personal Strategies to Minimise Effects of Air Pollution on Respiratory Health: Advice for Providers, Patients and the Public.” *European Respiratory Journal* 55 (6). https://doi.org/10.1183/13993003.02056-2019.

Chan, Chak K., and Xiaohong Yao. 2008. “Air Pollution in Mega Cities in China.” *Atmospheric Environment* 42 (1): 1–42. https://doi.org/10.1016/j.atmosenv.2007.09.003.

Chang, Man Kit. 1998. “Predicting Unethical Behavior: A Comparison of the Theory of Reasoned Action and the Theory of Planned Behavior.” *Journal of Business Ethics* 17 (16): 1825–1834. https://doi.org/10.1023/A:1005721401993.

Chen, Mei Fang, and Pei Ju Tung. 2014. “Developing an Extended Theory of Planned Behavior Model to Predict Consumers’ Intention to Visit Green Hotels.” *International Journal of Hospitality Management* 36: 221–230. https://doi.org/10.1016/j.ijhm.2013.09.006.

Cheng, Yang, Changlin Ao, Biqi Mao, and Lishan Xu. 2022. “Influential Factors of Environmental Behavior to Reduce Air Pollution: Integrating Theories of Planned Behavior and Psychological Distance.” *Journal of Environmental Planning and Management* 65 (13): 2490–2510. https://doi.org/10.1080/09640568.2021.1973972.

Cheung, Gordon W., Helena D. Cooper-Thomas, Rebecca S. Lau, and Linda C. Wang. 2023. “Reporting Reliability, Convergent and Discriminant Validity with Structural Equation Modeling: A Review and Best-Practice Recommendations.” *Asia Pacific Journal of Management*, ahead of print, 2023. https://doi.org/10.1007/s10490-023-09871-y.

Chin, Wynne W., Barbara L. Marcolin, and Peter R. Newsted. 2003. “A Partial Least Squares Latent Variable Modeling Approach for Measuring Interaction Effects: Results from a Monte Carlo Simulation Study and an Electronic-Mail Emotion/Adoption Study.” *Information Systems Research* 14 (2): 189–217. https://doi.org/10.1287/isre.14.2.189.16018.

Chowdhury, Sourangsu, Correspondence Harshal, Ramesh Salve, Harshal Ramesh Salve, Huma Nawaz, Sagnik Dey, Anand Krishnan, Preeti Sharma, and Karan Madan. 2024. “Effectiveness of Household-Level Interventions for Reducing the Impact of Air Pollution on Health Outcomes – a Systematic Review.” *Frontiers in Environmental Health* 3 (October): 1410966. https://doi.org/10.3389/FENVH.2024.1410966.

Clark, Maggie L., Jennifer L. Peel, Kalpana Balakrishnan, Patrick N. Breysse, Steven N. Chillrud, Luke P. Naeher, Charles E. Rodes, Alan F. Vette, and John M. Balbus. 2013. “Health and Household Air Pollution from Solid Fuel Use: The Need for Improved Exposure Assessment.” *Environmental Health Perspectives* 121 (10): 1120–1128. https://doi.org/10.1289/ehp.1206429.

Dai, Xilei, Junjie Liu, Xiangdong Li, and Lei Zhao. 2018. “Long-Term Monitoring of Indoor CO2 and PM2.5 in Chinese Homes: Concentrations and Their Relationships with Outdoor Environments.” *Building and Environment* 144 (October): 238–247. https://doi.org/10.1016/j.buildenv.2018.08.019.

Daniel, Laure, Marylou Michot, Maxime Esvan, Pauline Guérin, Guillaume Chauvet, and Fabienne Pelé. 2020. “Perceptions, Knowledge, and Practices Concerning Indoor Environmental Pollution of Parents or Future Parents.” *International Journal of Environmental Research and Public Health* 17 (20): 7669. https://doi.org/10.3390/ijerph17207669.

Dasgupta, S., M. Huq, M. Khaliquzzaman, K. Pandey, and D. Wheeler. 2006. “Indoor Air Quality for Poor Families: New Evidence from Bangladesh.” *Indoor Air* 16 (6): 426–444. https://doi.org/10.1111/j.1600-0668.2006.00436.x.

Dasgupta, S., M. Huq, M Khaliquzzaman, K. Pandey, and D. Wheeler. 2006. “Who Suffers from Indoor Air Pollution? Evidence from Bangladesh.” *Health Policy and Planning* 21 (6): 444–458. https://doi.org/10.1093/heapol/czl027.

Dasgupta, Susmita, Mainul Huq, M. Khaliquzzaman, Kiran Pandey, and David Wheeler. 2006. “Who Suffers from Indoor Air Pollution? Evidence from Bangladesh.” *Health Policy and Planning* 21 (6): 444–458. https://doi.org/10.1093/heapol/czl027.

Dedoussi, Irene C., Sebastian D. Eastham, Erwan Monier, and Steven R. H. Barrett. 2020. “Premature Mortality Related to United States Cross-State Air Pollution.” *Nature* 578 (7794): 261–265. https://doi.org/10.1038/s41586-020-1983-8.

Dioba, Albina, Valentina Kroker, Siegfried Dewitte, and Florian Lange. 2024. “Barriers to Pro-Environmental Behavior Change: A Review of Qualitative Research.” *Sustainability 2024, Vol. 16, Page 8776* 16 (20): 8776. https://doi.org/10.3390/SU16208776.

Domingo, José L., and Joaquim Rovira. 2020. “Effects of Air Pollutants on the Transmission and Severity of Respiratory Viral Infections.” *Environmental Research* 187 (August): 109650. https://doi.org/10.1016/j.envres.2020.109650.

Duan, Wenjie, and Junrong Sheng. 2018. “How Can Environmental Knowledge Transfer into Pro-Environmental Behavior among Chinese Individuals? Environmental Pollution Perception Matters.” *Journal of Public Health* 26 (3): 289–300. https://doi.org/10.1007/s10389-017-0873-5.

Dunlap, Riley E., and Kent D. Van Liere. 1978. “The ‘New Environmental Paradigm.’” *The Journal of Environmental Education* 9 (4): 10–19. https://doi.org/10.1080/00958964.1978.10801875.

Ezzati, Majid, and Daniel M Kammen. 2002. “Evaluating the Health Benefits of Transitions in Household Energy Technologies in Kenya.” *Energy Policy* 30 (10): 815–826. https://doi.org/10.1016/S0301-4215(01)00125-2.

Fakhri, Yadolah, Ibrahim Ziad Abdullah, Ayham Issam Qasem Al-issa, Elham Rahmanzadeh, Somayeh Hoseinvandtabar, Somayyeh Dehghani, Mahdi Ghorbanian, and Amin Ghanbarnejad. 2024. “Association between Short-Term Exposure to High-Level Particulate Matter (PM1, PM2. 5, and PM10) of Smoke Peganum Harmala Seeds with Blood Pressure: A Quasi-Experimental Study.” *Environmental Health Engineering And Management Journal*, 2024, 0–0.

Fehintola Awopeju, Olayemi. 2021. “Health Effect of Biomass Fuel Smoke.” In *Environmental Emissions*, edited by Richard Viskup. IntechOpen.

Ferdous, Tarana, Kamran Siddiqi, Sean Semple, Caroline Fairhurst, Ruaraidh Dobson, Noreen Mdege, Anna-Marie Marshall, S. M. Abdullah, and Rumana Huque. 2022. “Smoking Behaviours and Indoor Air Quality: A Comparative Analysis of Smoking-Permitted versus Smoke-Free Homes in Dhaka, Bangladesh.” *Tobacco Control* 31 (3): 444–451. https://doi.org/10.1136/tobaccocontrol-2020-055969.

Finlay, Krystina A., David Trafimow, and Eri Moroi. 1999. “The Importance of Subjective Norms on Intentions to Perform Health Behaviors.” *Journal of Applied Social Psychology* 29 (11): 2381–2393. https://doi.org/10.1111/j.1559-1816.1999.tb00116.x.

Fishbein, M. 1981. “Attitudes and Voting Behavior: An Application of the Theory of Reasoned Action.” *Progress in Applied Social Psychology/Wiley*, 1981.

Fornell, Claes, and David F. Larcker. 1981a. “Evaluating Structural Equation Models with Unobservable Variables and Measurement Error.” *Journal of Marketing Research* 18 (1): 39–50. https://doi.org/10.2307/3151312.

Fornell, Claes, and David F. Larcker. 1981b. “Evaluating Structural Equation Models with Unobservable Variables and Measurement Error.” *Journal of Marketing Research* (US) 18 (1): 39–50. https://doi.org/10.2307/3151312.

Fredricks, Arlene J., and Dennis L. Dossett. 1983. “Attitude–Behavior Relations: A Comparison of the Fishbein-Ajzen and the Bentler-Speckart Models.” *Journal of Personality and Social Psychology* 45 (3): 501.
Gifford, Robert, and Andreas Nilsson. 2014. “Personal and Social Factors That Influence Pro-Environmental Concern and Behaviour: A Review.” In *International Journal of Psychology*, 49:141–157. no. 3. Preprint. https://doi.org/10.1002/ijop.12034.
Gurley, Emily S., Henrik Salje, Nusrat Homaira, Pavani K. Ram, Rashidul Haque, William A. Petri, Joseph Bresee, et al. 2013. “Seasonal Concentrations and Determinants of Indoor Particulate Matter in a Low-Income Community in Dhaka, Bangladesh.” *Environmental Research* 121 (February): 11–16. https://doi.org/10.1016/j.envres.2012.10.004.
Habermehl, Helga. 2007. *Economic Evaluation of the Improved Household Cooking Stove Dissemination Programme in Uganda*. February 2007.
Hair, Joseph, William Black, Barry Babin, and Rolph Anderson. 2010. “Multivariate Data Analysis: A Global Perspective.” In *Multivariate Data Analysis: A Global Perspective*, vol. 7th.
Hassan, Md Shareful, Mohammad Amir Hossain Bhuiyan, and Muhammad Tauhidur Rahman. 2023. “Sources, Pattern, and Possible Health Impacts of PM2.5 in the Central Region of Bangladesh Using PMF, SOM, and Machine Learning Techniques.” *Case Studies in Chemical and Environmental Engineering* 8 (December): 100366. https://doi.org/10.1016/j.cscee.2023.100366.
Holgate, Stephen T. 2017. “‘Every Breath We Take: The Lifelong Impact of Air Pollution’ – a Call for Action.” *Clinical Medicine* 17 (1): 8–12. https://doi.org/10.7861/clinmedicine.17-1-8.
Hossain, Md. Maruf. 2019. “Study on Ambient Particulate Matter (PM2.5) with Different Mode of Transportation in Dhaka City, Bangladesh.” *American Journal of Pure and Applied Biosciences* 1 (4): 12–19. https://doi.org/10.34104/ajpab.019.0191219.
Hu, Huan, Jinhe Zhang, Chang Wang, Peng Yu, and Guang Chu. 2019. “What Influences Tourists’ Intention to Participate in the Zero Litter Initiative in Mountainous Tourism Areas: A Case Study of Huangshan National Park, China.” *Science of the Total Environment* 657: 1127–1137. https://doi.org/10.1016/j.scitotenv.2018.12.114.
Hung, Ming Feng, Chiung Ting Chang, and Daigee Shaw. 2019. “Individuals’ Intentions to Mitigate Air Pollution: Vehicles, Household Appliances, and Religious Practices.” *Journal of Cleaner Production* 227: 566–577. https://doi.org/10.1016/j.jclepro.2019.04.163.
Imarhiagbe, Odoligie, Miriam U. Nwodo, and Matthew Chidozie Ogwu. 2024. “Innovations for Cleaner Futures: Emerging Technologies in Air Pollution Mitigation.” In *Sustainable Strategies for Air Pollution Mitigation: Development, Economics, and Technologies*, edited by Matthew Chidozie Ogwu and Sylvester Chibeuze Izah, 377–407. Cham: Springer Nature Switzerland. https://doi.org/10.1007/698_2024_1124.
IQAir. 2024. *World Air Quality Report*. IQAir. https://www.iqair.com/world-air-quality-report.
Irfan, Muhammad, Michael P. Cameron, and Gazi Hassan. 2021. “Interventions to Mitigate Indoor Air Pollution: A Cost-Benefit Analysis.” *PLoS ONE* 16 (9 September). https://doi.org/10.1371/journal.pone.0257543.
Jeon, Sehyeok, Seoyong Kim, and Sohee Kim. 2024. “Who Pays for Clean Air, and Why?: Analyzing the Impact of Resource, Planned Behavior, and Government/Policy Factors on the Multidimensional Willingness to Pay for Reducing the Particulate Matter.” *Heliyon* 10 (15). https://doi.org/10.1016/j.heliyon.2024.e34643.
Jeuland, Marc, Jie-Sheng Tan Soo, and Drew Shindell. 2018. “The Need for Policies to Reduce the Costs of Cleaner Cooking in Low Income Settings: Implications from

Systematic Analysis of Costs and Benefits." *Energy Policy* 121 (October): 275–285. https://doi.org/10.1016/j.enpol.2018.06.031.
Johnson, Michael, Ajay Pillarisetti, Ricardo Piedrahita, Kalpana Balakrishnan, Jennifer L. Peel, Kyle Steenland, Lindsay J. Underhill, et al. 2022. "Exposure Contrasts of Pregnant Women during the Household Air Pollution Intervention Network Randomized Controlled Trial." *Environmental Health Perspectives* 130 (9): 097005. https://doi.org/10.1289/EHP10295.
Kaiser, Florian G., and Alexandra Kibbe. 2017. "Pro-Environmental Behavior ☆." In *Reference Module in Neuroscience and Biobehavioral Psychology*, B9780128093245055127. Elsevier.
Khajeamiri, Yasaman, Samira Sharifi, Nioosha Moradpour, and Alireza Khajeamiri. 2021. "A Review on the Effect of Air Pollution and Exposure to PM, NO2 , O3 , SO2 , CO and Heavy Metals on Viral Respiratory Infections." *Journal of Air Pollution and Health*, ahead of print, June 2021. https://doi.org/10.18502/japh.v5i4.6445.
Khalequzzaman, Md., Michihiro Kamijima, Kiyoshi Sakai, Bilqis Amin Hoque, and Tamie Nakajima. 2010. "Indoor Air Pollution and the Health of Children in Biomass- and Fossil-Fuel Users of Bangladesh: Situation in Two Different Seasons." *Environmental Health and Preventive Medicine* 15 (4): 236–243. https://doi.org/10.1007/s12199-009-0133-6.
Khomenko, Sasha, Marta Cirach, Evelise Pereira-Barboza, Natalie Mueller, Jose Barrera-Gómez, David Rojas-Rueda, Kees De Hoogh, Gerard Hoek, and Mark Nieuwenhuijsen. 2021. "Premature Mortality Due to Air Pollution in European Cities: A Health Impact Assessment." *The Lancet Planetary Health* 5 (3): e121–e134. https://doi.org/10.1016/S2542-5196(20)30272-2.
Knussen, Christina, Fred Yule, Julie MacKenzie, and Mark Wells. 2004. "An Analysis of Intentions to Recycle Household Waste: The Roles of Past Behaviour, Perceived Habit, and Perceived Lack of Facilities." *Journal of Environmental Psychology* 24 (2): 237–246. https://doi.org/10.1016/j.jenvp.2003.12.001.
Kollmuss, Anja, and Julian Agyeman. 2002. "Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to pro-Environmental Behavior?" *Environmental Education Research* 8 (3): 239–260. https://doi.org/10.1080/13504620220145401.
Kumar, Pradeep, A. B. Singh, Taruna Arora, Sevaram Singh, and Rajeev Singh. 2023. "Critical Review on Emerging Health Effects Associated with the Indoor Air Quality and Its Sustainable Management." *Science of The Total Environment* 872 (May): 162163. https://doi.org/10.1016/j.scitotenv.2023.162163.
Kumar, Praveen, and Leah Igdalsky. 2019. "Sustained Uptake of Clean Cooking Practices in Poor Communities: Role of Social Networks." In *Energy Research and Social Science*, 48:189–193. Preprint. https://doi.org/10.1016/j.erss.2018.10.008.
Kurata, Masamitsu, Kazushi Takahashi, and Akira Hibiki. 2020. "Gender Differences in Associations of Household and Ambient Air Pollution with Child Health: Evidence from Household and Satellite-Based Data in Bangladesh." *World Development* 128 (April): 104779. https://doi.org/10.1016/j.worlddev.2019.104779.
Kureshi, Rameezraja, Dhavalkumar Thakker, Bhupesh Mishra, and Jo Barnes. 2023. "From Raising Awareness to a Behavioural Change: A Case Study of Indoor Air Quality Improvement Using IoT and COM-B Model." *Sensors* 23 (March): 3613. https://doi.org/10.3390/s23073613.
Leeuw, Astrid De, Pierre Valois, Icek Ajzen, and Peter Schmidt. 2015. "Using the Theory of Planned Behavior to Identify Key Beliefs Underlying Pro-Environmental Behavior in High-School Students: Implications for Educational Interventions." *Journal of Environmental Psychology* 42 (June): 128–138. https://doi.org/10.1016/j.jenvp.2015.03.005.

Liang, Wei, and Ming Yang. 2019. "Urbanization, Economic Growth and Environmental Pollution: Evidence from China." *Sustainable Computing: Informatics and Systems* 21 (March): 1–9. https://doi.org/10.1016/j.suscom.2018.11.007.

Lipi, Afroza, and Nazmul Hasan. 2021. "URBANIZATION IN BANGLADESH: EMERGING CHALLENGES AND THE WAY FORWARD." *Bangladesh Journal of Multidisciplinary Scientific Research* 3 (May): 33–44. https://doi.org/10.46281/bjmsr.v3i1.1112.

Liu, Cong, Jing Cai, Renjie Chen, Francesco Sera, Yuming Guo, Shilu Tong, Shanshan Li, et al. 2022. "Coarse Particulate Air Pollution and Daily Mortality: A Global Study in 205 Cities." *American Journal of Respiratory and Critical Care Medicine* 206 (8): 999–1007. https://doi.org/10.1164/rccm.202111-2657OC.

Liu, Qian, Cheng Xu, Guixiang Ji, Hui Liu, Wentao Shao, Chunlan Zhang, Aihua Gu, and Peng Zhao. 2017. "Effect of Exposure to Ambient PM2.5 Pollution on the Risk of Respiratory Tract Diseases: A Meta-Analysis of Cohort Studies." *Journal of Biomedical Research* 31 (2): 130–142. https://doi.org/10.7555/JBR.31.20160071.

Liu, Qingyang, Young Joo Son, Linhao Li, Nadia Wood, Araliya M. Senerat, and Jovan Pantelic. 2022. "Healthy Home Interventions: Distribution of PM2.5 Emitted during Cooking in Residential Settings." *Building and Environment* 207 (January): 108448. https://doi.org/10.1016/j.buildenv.2021.108448.

Liu, Shumei, Yi-Te Chiang, Chie-Chien Tseng, Eric Ng, Gwo-Liang Yeh, and Wei-Ta Fang. 2018a. "The Theory of Planned Behavior to Predict Protective Behavioral Intentions against PM2.5 in Parents of Young Children from Urban and Rural Beijing, China." *International Journal of Environmental Research and Public Health* 15 (10): 2215. https://doi.org/10.3390/ijerph15102215.

Liu, Shumei, Yi-Te Chiang, Chie-Chien Tseng, Eric Ng, Gwo-Liang Yeh, and Wei-Ta Fang. 2018b. "The Theory of Planned Behavior to Predict Protective Behavioral Intentions against PM2.5 in Parents of Young Children from Urban and Rural Beijing, China." *International Journal of Environmental Research and Public Health* 15 (10): 2215. https://doi.org/10.3390/ijerph15102215.

Liu, Xuan, Qian Cheng Wang, Izzy Yi Jian, Hung Lin Chi, Dujuan Yang, and Edwin Hon Wan Chan. 2021. "Are You an Energy Saver at Home? The Personality Insights of Household Energy Conservation Behaviors Based on Theory of Planned Behavior." *Resources, Conservation and Recycling* 174. https://doi.org/10.1016/j.resconrec.2021.105823.

Lou, Xiaobin, and Liman Man Wai Li. 2023. "The Relationship of Environmental Concern with Public and Private Pro-environmental Behaviours: A Pre-registered Meta-analysis." *European Journal of Social Psychology* 53 (1): 1–14. https://doi.org/10.1002/ejsp.2879.

Maloney, Michael P., and Michael P. Ward. 1973. "Ecology: Let's Hear from the People: An Objective Scale for the Measurement of Ecological Attitudes and Knowledge." *American Psychologist* 28 (7): 583.

Manisalidis, Ioannis, Elisavet Stavropoulou, Agathangelos Stavropoulos, and Eugenia Bezirtzoglou. 2020. "Environmental and Health Impacts of Air Pollution: A Review." *Frontiers in Public Health* 8 (February): 14. https://doi.org/10.3389/fpubh.2020.00014.

Manstead, Anthony S., Christine Proffitt, and J. L. Smart. 1983. "Predicting and Understanding Mothers' Infant-Feeding Intentions and Behavior: Testing the Theory of Reasoned Action." *Journal of Personality and Social Psychology* 44 (4): 657.

McCarron, Amy, Sean Semple, Christine Braban, Vivien Swanson, Colin Gillespie, and Heather Price. 2022. "Public Engagement with Air Quality Data: Using Health Behaviour Change Theory to Support Exposure-Minimising Behaviours." *Journal of*

Exposure Science & Environmental Epidemiology 33 (June): 1–11. https://doi.org/10.1038/s41370-022-00449-2.
Pakravan, Mohammad H., and Nordica MacCarty. 2020. “What Motivates Behavior Change? Analyzing User Intentions to Adopt Clean Technologies in Low-Resource Settings Using the Theory of Planned Behavior.” *Energies* 13 (11). https://doi.org/10.3390/en13113021.
Pan, Lihua, Xia Zhang, Sizhe Wang, Nan Zhao, Ran Zhao, Bogui Ding, Ying Li, Wenxue Miao, and Hong Fan. 2023. “Determinants Associated with Self-Management Behavior among Type 2 Diabetes Patients in China: A Structural Equation Model Based on the Theory of Planned Behavior.” *International Journal of Clinical and Health Psychology : IJCHP* 23 (1): 100332. https://doi.org/10.1016/j.ijchp.2022.100332.
Park, Seona, Hyun Suk Kim, and Sun-Jin Yun. 2022. “Predicting PM2.5 Reduction Behavior among College Students: The Role of Beliefs and Descriptive Norms.” *Sustainable Environment* 8 (1): 2079190. https://doi.org/10.1080/27658511.2022.2079190.
Paul, Justin, Ashwin Modi, and Jayesh Patel. 2016. “Predicting Green Product Consumption Using Theory of Planned Behavior and Reasoned Action.” *Journal of Retailing and Consumer Services* 29 (March): 123–134. https://doi.org/10.1016/j.jretconser.2015.11.006.
Paulraj, Antony, Augustine A. Lado, and Injazz J. Chen. 2008. “Inter-Organizational Communication as a Relational Competency: Antecedents and Performance Outcomes in Collaborative Buyer–Supplier Relationships.” *Journal of Operations Management* 26 (1): 45–64. https://doi.org/10.1016/j.jom.2007.04.001.
Pekey, Hakan, Beyhan Pekey, Demet Arslanbaş, Zehra Bulut Bozkurt, Güray Doğan, and Gürdal Tuncel. 2013. “Source Apportionment of Personal Exposure to Fine Particulate Matter and Volatile Organic Compounds Using Positive Matrix Factorization.” *Water, Air, & Soil Pollution* 224 (1): 1403. https://doi.org/10.1007/s11270-012-1403-2.
Population and Housing Census. 2022. *Population and Housing Census*. Ministry of Planning, Government of the People’s Republic of Bangladesh. https://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/b343a8b4_956b_45ca_872f_4cf9b2f1a6e0/2024-01-31-15-51-b53c55dd692233ae401ba013060b9cbb.pdf.
Povey, Rachel, Mark Conner, Paul Sparks, Rhiannon James, and Richard Shepherd. 2000. “The Theory of Planned Behaviour and Healthy Eating: Examining Additive and Moderating Effects of Social Influence Variables.” *Psychology & Health* 14 (6): 991–1006. https://doi.org/10.1080/08870440008407363.
Pronello, Cristina, and Jean-Baptiste Gaborieau. 2018. “Engaging in Pro-Environment Travel Behaviour Research from a Psycho-Social Perspective: A Review of Behavioural Variables and Theories.” *Sustainability* 10 (7): 7. https://doi.org/10.3390/su10072412.
Puzzolo, Elisa, Daniel Pope, Debbi Stanistreet, Eva A. Rehfuess, and Nigel G. Bruce. 2016. “Clean Fuels for Resource-Poor Settings: A Systematic Review of Barriers and Enablers to Adoption and Sustained Use.” *Environmental Research* 146 (April): 218–234. https://doi.org/10.1016/j.envres.2016.01.002.
Qualtrics. 2023. “Sample Size Calculator.” Qualtrics, March.
Rahman, Md Mostafijur, Bilkis A. Begum, Philip K. Hopke, Kamrun Nahar, and George D. Thurston. 2020. “Assessing the PM2.5 Impact of Biomass Combustion in Megacity Dhaka, Bangladesh.” *Environmental Pollution* 264 (September): 114798. https://doi.org/10.1016/j.envpol.2020.114798.
Raju, Sarath, Trishul Siddharthan, and Meredith C. McCormack. 2020. “Indoor Air Pollution and Respiratory Health.” *Clinics in Chest Medicine* 41 (4): 825–843. https://doi.org/10.1016/j.ccm.2020.08.014.

Ram, Pavani K., Dhiman Dutt, Benjamin J. Silk, Saumil Doshi, Carole B. Rudra, Jaynal Abedin, Doli Goswami, et al. 2014. "Household Air Quality Risk Factors Associated with Childhood Pneumonia in Urban Dhaka, Bangladesh." *The American Society of Tropical Medicine and Hygiene* 90 (5): 968–975. https://doi.org/10.4269/ajtmh.13-0532.

Ramírez, A. Susana, Steven Ramondt, Karina Van Bogart, and Raquel Perez-Zuniga. 2019. "Public Awareness of Air Pollution and Health Threats: Challenges and Opportunities for Communication Strategies To Improve Environmental Health Literacy." *Journal of Health Communication* 24 (1): 75–83. https://doi.org/10.1080/10810730.2019.1574320.

Ramsey, Charles E., and Roy E. Rickson. 1976. "Environmental Knowledge and Attitudes." *The Journal of Environmental Education*, October 1976.

Rawat, Nidhi, and Prashant Kumar. 2023. "Interventions for Improving Indoor and Outdoor Air Quality in and around Schools." *Science of The Total Environment* 858 (February): 159813. https://doi.org/10.1016/j.scitotenv.2022.159813.

Ru, Xingjun, Haibo Qin, and Shanyong Wang. 2019. "Young People's Behaviour Intentions towards Reducing PM2.5 in China: Extending the Theory of Planned Behaviour." *Resources, Conservation and Recycling* 141: 99–108. https://doi.org/10.1016/j.resconrec.2018.10.019.

Ru, Xingjun, Shanyong Wang, and Shuai Yan. 2018. "Exploring the Effects of Normative Factors and Perceived Behavioral Control on Individual's Energy-Saving Intention: An Empirical Study in Eastern China." *Resources, Conservation and Recycling* 134 (July): 91–99. https://doi.org/10.1016/j.resconrec.2018.03.001.

Salje, H., E. S. Gurley, N. Homaira, P. K. Ram, R. Haque, W. Petri, W. J. Moss, S. P. Luby, P. Breysse, and E. Azziz-Baumgartner. 2014. "Impact of Neighborhood Biomass Cooking Patterns on Episodic High Indoor Particulate Matter Concentrations in Clean Fuel Homes in Dhaka, Bangladesh." *Indoor Air* 24 (2): 213–220. https://doi.org/10.1111/ina.12065.

Sánchez-García, Mercedes, Ferdaous Zouaghi, Fernando Lera-López, and Javier Faulin. 2021. "An Extended Behavior Model for Explaining the Willingness to Pay to Reduce the Air Pollution in Road Transportation." *Journal of Cleaner Production* 314. https://doi.org/10.1016/j.jclepro.2021.128134.

Saphores, Jean Daniel M., Oladele A. Ogunseitan, and Andrew A. Shapiro. 2012. "Willingness to Engage in a Pro-Environmental Behavior: An Analysis of e-Waste Recycling Based on a National Survey of U.S. Households." *Resources, Conservation and Recycling* 60: 49–63. https://doi.org/10.1016/j.resconrec.2011.12.003.

Saraga, Dikaia E., Xavier Querol, Regina M. B. O. Duarte, Noel J. Aquilina, Nuno Canha, Elena Gómez Alvarez, Milena Jovasevic-Stojanovic, et al. 2023. "Source Apportionment for Indoor Air Pollution: Current Challenges and Future Directions." *Science of The Total Environment* 900 (November): 165744. https://doi.org/10.1016/j.scitotenv.2023.165744.

Sarkodie, Samuel Asumadu, Vladimir Strezov, Yijiao Jiang, and Tim Evans. 2019. "Proximate Determinants of Particulate Matter (PM2.5) Emission, Mortality and Life Expectancy in Europe, Central Asia, Australia, Canada and the US." *Science of The Total Environment* 683 (September): 489–497. https://doi.org/10.1016/j.scitotenv.2019.05.278.

Shi, Haixia, Jin Fan, and Dingtao Zhao. 2017. "Predicting Household PM2.5-Reduction Behavior in Chinese Urban Areas: An Integrative Model of Theory of Planned Behavior and Norm Activation Theory." *Journal of Cleaner Production* 145: 64–73. https://doi.org/10.1016/j.jclepro.2016.12.169.

Shi, Haixia, Shanyong Wang, and Dingtao Zhao. 2017a. "Exploring Urban Resident's Vehicular PM2.5 Reduction Behavior Intention: An Application of the Extended

Theory of Planned Behavior." *Journal of Cleaner Production* 147: 603–613. https://doi.org/10.1016/j.jclepro.2017.01.108.
Shi, Haixia, Shanyong Wang, and Dingtao Zhao. 2017b. "Exploring Urban Resident's Vehicular PM2.5 Reduction Behavior Intention: An Application of the Extended Theory of Planned Behavior." *Journal of Cleaner Production* 147: 603–613. https://doi.org/10.1016/j.jclepro.2017.01.108.
Siddiqui, Shafayet Ahmed, Md Jakaria, Mohammad Nurul Amin, Abdullah Al Mahmud, and David Gozal. 2020. "Chronic Air Pollution and Health Burden in Dhaka City." In *European Respiratory Journal*, vol. 56. no. 2. Preprint. https://doi.org/10.1183/13993003.00689-2020.
Sun, Zhiying, Chen Chen, Dandan Xu, and Tiantian Li. 2018. "Effects of Ambient Temperature on Myocardial Infarction: A Systematic Review and Meta-Analysis." *Environmental Pollution* 241 (October): 1106–1114. https://doi.org/10.1016/j.envpol.2018.06.045.
Takács-Sánta, András. 2007. "Barriers to Environmental Concern." *Human Ecology Review*, 2007, 26–38.
Timilsina, Govinda R., and Sunil Malla. 2021. "Clean Cooking: Why Is Adoption Slow Despite Large Health and Environmental Benefits?" *Economics of Energy & Environmental Policy* 10 (1). https://doi.org/10.5547/2160-5890.9.1.gtim.
Tran, Vinh Van, Duckshin Park, and Young-Chul Lee. 2020. "Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality." *International Journal of Environmental Research and Public Health* 17 (8): 2927. https://doi.org/10.3390/ijerph17082927.
Vardoulakis, Sotiris, Evanthia Giagloglou, Susanne Steinle, Alice Davis, Anne Sleeuwenhoek, Karen S. Galea, Ken Dixon, and Joanne O. Crawford. 2020. "Indoor Exposure to Selected Air Pollutants in the Home Environment: A Systematic Review." *International Journal of Environmental Research and Public Health* 17 (23): 8972. https://doi.org/10.3390/ijerph17238972.
Venuto, Roberto, Roberta Pappalardo, Cristina Genovese, Giuseppe Trimarchi, Raffaele Squeri, Giuseppe La Spada, and Vincenza La Fauci. 2024. "Indoor Air Pollution: An Italian Knowledge, Attitude and Practice (KAP) Study among the General Population." *Annali Di Igiene: Medicina Preventiva E Di Comunita* 36 (6): 683–694. https://doi.org/10.7416/ai.2024.2640.
Wang, Lina, Xiaoming Wu, Jianqiang Du, Wangnan Cao, and Shengzhi Sun. 2021. "Global Burden of Ischemic Heart Disease Attributable to Ambient PM2.5 Pollution from 1990 to 2017." *Chemosphere* 263 (January): 128134. https://doi.org/10.1016/j.chemosphere.2020.128134.
Wang, Lina, Xinran Zheng, Svetlana Stevanovic, Zhiyuan Xiang, Jing Liu, Huiwen Shi, Jing Liu, Mingzhou Yu, and Chun Zhu. 2018. "Characterizing Pollutant Emissions from Mosquito Repellents Incenses and Implications in Risk Assessment of Human Health." *Chemosphere* 191 (January): 962–970. https://doi.org/10.1016/j.chemosphere.2017.09.097.
Wang, Siyuan, Rong Song, Zhiwei Xu, Mingsheng Chen, Gian Luca Di Tanna, Laura Downey, Stephen Jan, and Lei Si. 2024. "The Costs, Health and Economic Impact of Air Pollution Control Strategies: A Systematic Review." *Global Health Research and Policy* 9 (1): 30. https://doi.org/10.1186/s41256-024-00373-y.
Wang, Yilin, Mengqiu Cao, Yuqi Liu, Runing Ye, Xing Gao, and Liang Ma. 2022. "Public Transport Equity in Shenyang: Using Structural Equation Modelling." *Research in Transportation Business and Management* 42. https://doi.org/10.1016/j.rtbm.2020.100555.
Weichenthal, Scott, Eric Lavigne, Greg Evans, Krystal Pollitt, and Rick T. Burnett. 2016. "Ambient PM2.5 and Risk of Emergency Room Visits for Myocardial Infarction:

Impact of Regional PM2.5 Oxidative Potential: A Case-Crossover Study." *Environmental Health* 15 (1): 46. https://doi.org/10.1186/s12940-016-0129-9.
Weng, Yu-Ling, Chin-Chia Liang, Chie-Chien Tseng, Shih-Yi Lee, and Gwo-Liang Yeh. 2021. "A Survey of PM2.5 Preventive Behavioral Intention and Related Factors among Community Elderly in Northern Taiwan." *Medicine* 100 (29): e26675. https://doi.org/10.1097/MD.0000000000026675.
Woo, Siu Kei, Chih Jui Pai, Yi Te Chiang, and Wei Ta Fang. 2023. "Predicting the Protective Behavioral Intentions for Parents with Young Children Living in Taipei City and New Taipei City Using the Theory of Planned Behavior for Air Polluted with PM2.5." *International Journal of Environmental Research and Public Health* 20 (3). https://doi.org/10.3390/ijerph20032518.
Woo, Siu-Kei, Ben LePage, Yi-Te Chiang, and Wei-Ta Fang. 2022. "Predicting the Protective Behavioral Intentions for Parents with Young Children That Possess Different Levels of Education in Hong Kong Using the Theory of Planned Behavior for Air Polluted with PM2.5." *BMC Public Health* 22 (1): 761. https://doi.org/10.1186/s12889-022-13141-9.
Wyss, Annika M., Daria Knoch, and Sebastian Berger. 2022. "When and How Pro-Environmental Attitudes Turn into Behavior: The Role of Costs, Benefits, and Self-Control." *Journal of Environmental Psychology* 79. https://doi.org/10.1016/j.jenvp.2021.101748.
Xia, Tian, Julia Raneses, Brixon Schmiesing, Raquel Garcia, Alison Walding, Richardo DeMajo, Amy Schulz, and Stuart A. Batterman. 2024. "How Teacher Behaviors and Perceptions, Air Change Rates, and Portable Air Purifiers Affect Indoor Air Quality in Naturally Ventilated Schools." *Frontiers in Public Health* 12 (October). https://doi.org/10.3389/fpubh.2024.1427116.
Xie, Jinchen, and Chuntian Lu. 2022. "Relations among Pro-Environmental Behavior, Environmental Knowledge, Environmental Perception, and Post-Materialistic Values in China." *International Journal of Environmental Research and Public Health* 19 (1): 537. https://doi.org/10.3390/ijerph19010537.
Yang, Xiaorong, Tongchao Zhang, Xiangwei Zhang, Chong Chu, and Shaowei Sang. 2022. "Global Burden of Lung Cancer Attributable to Ambient Fine Particulate Matter Pollution in 204 Countries and Territories, 1990–2019." *Environmental Research* 204 (March): 112023. https://doi.org/10.1016/j.envres.2021.112023.
Yasmin, Afsana, Imran Ahmed, Maria Haider, Md. Kamal Hossain, Mohammad Abdul Motalib, and Md. Shakhaoat Hossain. 2024. "Characterizing Indoor Air Quality and Identifying Factors Influencing Air Quality at Home Microenvironment in Dhaka City." *Indoor Environments* 1 (4): 100056. https://doi.org/10.1016/j.indenv.2024.100056.
Zahedi, Siamak, Joan Manuel Batista-Foguet, and Lucas van Wunnik. 2019. "Exploring the Public's Willingness to Reduce Air Pollution and Greenhouse Gas Emissions from Private Road Transport in Catalonia." *Science of the Total Environment* 646: 850–861. https://doi.org/10.1016/j.scitotenv.2018.07.361.
Zhang, Lili, John P. Wilson, Na Zhao, Wenhao Zhang, and Yu Wu. 2022. "The Dynamics of Cardiovascular and Respiratory Deaths Attributed to Long-Term PM2.5 Exposures in Global Megacities." *Science of The Total Environment* 842 (October): 156951. https://doi.org/10.1016/j.scitotenv.2022.156951.