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Impact of Indoor Air Pollution on Health Outcomes in Pakistan: A Case Study of Multan District

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ABSTRACT

The current study intends to investigate the impact of indoor air pollution on health outcomes in Pakistan using data from 400 households in the Multan district. In order to find the presence of Indoor air pollution, readings of PM2.5 is used. The ordinary least square (OLS) method is used for data analysis. The study finds that indoor air pollution has a significant impact on physical and behavioural health symptoms. The study also finds that household head age, household size, household income, environmental concern, and the use of air cleaning device are the significant factors of physical health symptoms, while the variables household head age, education, household income, environmental concern, and environmental awareness are the significant factors of behavioural health symptoms. It is concluded that indoor air quality is essential in influencing the health status of the households. This study suggests that attempts should be made to improve indoor air quality by improving the housing structure and the socioeconomic status of the households.

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1. Introduction

Indoor environmental factors significantly impact human well-being since most individuals spend 90 percent of their time at home (Leech, Nelson, Burnett, Aaron, & Raizenne, 2002). Obanolu & Kiper (2006) defines indoor settings as "basic environmental elements that influence health". Indoor air quality is crucial factor that impacts health of the individuals, their well-being and productivity. As exposure time and density of air pollution grows, so it affects the human health adversely (Li et al., 2007). Indoor air quality has a considerable influence on human health. Toxic gases or vapors, metals, macromolecules, or particles that become suspended can pollute indoor air. Pollutants can indeed be biological or chemical in nature. Indoor pollution can cause a variety of physiological impacts, from olfactory perception to respiratory tract irritation to serious organ damage, immunological responses, and cancer (Arcus-Arth, Broadwin, & Lam, 2009). Cooking with firewood is a typical practice in most rural communities. Its usage as an energy source has been extensively recognized to have negative effects on the environment, notably on air quality and population health, particularly among women (Ana, Adeniji, Ige, Oluwole, & Olopade, 2013).

The influence of air pollutants on humans is assessed by their toxicity, concentration, and exposure time and may differ from one individual to the next. Sick building syndrome (SBS) is the most prevalent result, in which people feel unpleasant or acute health impacts such as nose, eye, and throat irritation, skin illnesses, and allergies. However, the syndrome is diminished when vulnerable individuals are supposed to leave that workplace or building. The SBS can be minimized by improving the house's ventilation system to improve indoor air quality (Wargocki, Wyon, Clausen, & Fanger, 2000). IAQ is also significantly impacted by housing structure. Housing is a key setting that impacts human health because individuals spend the most time in a house (Bonnefoy, Braubach, Krapavickaite, Ormand, & Zurlyte, 2003). Housing has long been recognized as a key factor in health. Housing and health are strongly intertwined (Smith, Alexander, & Easterlow, 1997). Indoor air pollution leads to different health problems such as Dida, Lutta, Abuom, Mestrovic, and Anyona (2022); Khalequzzaman et al. (2007); Maharana, Paul, Garg, Dasgupta, and Bandyopadhyay (2018); Ranabhat et al. (2015) reported eye problems. Rahman (2004); Singh and Jamal (2012) reported acute upper and lower respiratory infections, chronic obstructive pulmonary disease, asthma, perinatal mortality, pulmonary tuberculosis, low birth weight, eye irritation, and cataracts.

In Pakistan, over 62 percent of the population lives in rural regions. Rural households rely on biomass fuels 94 percent, whereas urban households rely on biomass fuels 58 percent. The combustion efficiency of these solid fuels is low. The resultant smoke contains various health-degrading chemicals that, at variable quantities, can represent a major hazard to human health due to the incomplete combustion of biomass fuels. IAP is responsible for 28,000 fatalities and 40 million cases of acute respiratory disease each year. An annual cost of 1 percent of GDP is a considerable financial burden for Pakistan (Environmental Science Review Pakistan, 2018).

As far as Multan district is concerned, it is located in Southern Punjab, where most of the population resides in rural areas. Due to the people's low economic status, they use unclean fuels for cooking, which causes bad indoor quality and influences their health. It is crucial to analyze the impact of indoor air pollution on health outcomes in Multan district as no study in the literature analyzed this association, particularly in the case of Multan district. So this study will provide important implications to the policymakers especially related to health that why indoor air quality is essential for the sake of improving human health. Moreover, the main objective of the study is to examine how indoor air pollution influences the health status of the households of the Multan district, and the current situation of indoor air pollution in Multan district. The organization of the study is as follows: section 1 discusses the introduction, section 2 demonstrates the literature review, section 3 presents the data and methodology, section 4 illustrates the data analysis, and section 5 presents the conclusions and policy recommendations.

2. Literature Review

Different studies analyzed the influence of IAP on human health; the literature review of some of the studies has been presented as follows: Dida et al. (2022) investigated the association between exposure to IAP and the self-reported prevalence of respiratory outcomes among women and children in Kenya. Wood and paraffin were discovered to be the most popular fuel options for cooking (96.8% and 97.4%, respectively). The primary source of IAP was determined to be wood smoke (96.8%). Most women (92.0%) and kids (95.4%) coughed during the year whereas 31.5% of the women experienced wheezing. Women and children who used wood fuel reported more coughing, phlegm, wheezing, eye issues, and headaches. The study also showed that health consequences of IAP were substantially correlated with education level, ventilation, primary fuel source, indoor cooking, and dwelling type. Priyadarsini, Ibrahim, Somasundaram, Nayeem, and Balasubramanian (2022) examined the influence of IAP on health. The findings showed that 17.7% of the homes utilized mosquito coils in the evening and at night, and 52.3% of the participants used incense sticks at home. Additionally, 66.4% of homes lacked a chimney or exhaust, and 29.5% reported being overcrowded. Additionally, the findings indicated that 71.4% of homes had tried opening windows while cooking. About 34.5% of female respondents reported experiencing IAP symptoms, which included dizziness (12.3%), eye irritation (10.2%), running nose (1.4%), dry cough (3.06%), breathing difficulties (4.5%), and nasal congestion (1.1%).

Ahmed, Shuai, Abbas, Rehman, and Khoso (2022) observed the association between the health of women and household air pollution. The findings showed that age at sterilization, place of residence, level of education, and the type of cooking fuel was the most important factor for a woman’s health. Additionally, cooking locations have a negative impact on the age of sterilization. Ali et al. (2021) explored the association between the usage of solid fuel and the health of women and children. By activating multiple toxicity mechanisms, including oxidative stress, gene activation DNA and methylation, these contaminants can cause a variety of health hazards. Low birth weight, anemia, acute lower respiratory tract infections, and early mortality were more common in exposed children. In contrast, the key factors of incapacity and early mortality in women were cardiovascular disorders, lung cancer, and chronic obstructive pulmonary disease.

Rajper, Nazir, Ullah, and Li (2020) examined the perceived health symptoms in rural households related to IAP. The findings showed that fossil fuels favorably impacted the health of individuals in a household. Y. Chen and Chen (2020) evaluated the combined impact of indoor air quality and socioeconomic variables on occupants' health in China. The socioeconomic position directly influenced residents' health and socioeconomic status directly impacted indoor air quality. Jiao, Xu, and Liu (2018) explored the relationship between exposure to air pollution and health impacts in China while considering socioeconomic factors. The results showed a non-linear association between community socioeconomic status and local air pollution in metropolitan China, with communities of moderate socioeconomic class having the greatest levels of air pollution. In addition, not all socioeconomic status groups experienced the same health effects of air pollution. The analysis also found that households with low socioeconomic status were influenced more by IAP.

Maharana et al. (2018) examined the causes of IAP and its impact on health of women in India. The analysis showed that Kerosene was the primary cooking fuel in almost 60% of homes and 60% of homes had too many occupants, and more than 70% had improper ventilation. IAP sources and their contributing components were substantially linked with symptoms, including dry cough, suffocation, and eye discomfort. IAP was perceived to be present in homes by 65% of people. A higher likelihood of IAP sources was found to be associated with coupled families, lower per capita income, and ground-floor residences. Higher contributory components of IAP were highly correlated with younger age, lower PCI, and ground floor. Kim, Kang, and Kim (2018) assessed the concentration of cooking-generated particles. The analysis showed that the living room had a somewhat higher concentration of $PM_{2.5}$compared to the kitchen. Additionally, the health risk rose to 30.8% more than it would under the baseline scenario.

Khalequzzaman et al. (2007) analyzed the dust particles, carbon dioxide, nitrogen dioxide, and volatile organic compounds concentrations in indoor air in Dhaka, Bangladesh. The geometric mean concentrations of benzene, xylene, toluene, hexane, total VOCs, and NO_2 were found to be substantially greater in the users of fossil fuels than in the users of biomass fuels. Using biomass fuel was linked to symptoms like red eyes, itchy skin, nasal discharge, cough, shortness of breath, chest tightness, wheezing, or whistling chest. Akhtar, Ullah, Khan, and Nazli (2007) found a strong correlation between biomass smoke and chronic bronchitis in females living in rural Peshawar. Both 1,131 female control individuals who used liquefied petroleum gas and 1,426 female test volunteers who used various biomass fuels were employed in this investigation. The findings demonstrated that using biomass as an energy source was harmful to human health. Rahman (2004) studied indoor air pollution and its effects on public health in Aligarh, India. According to the study, more than 50% of the Aligarh city people in the sample had respiratory issues. This was attributed to IAP, crowded living conditions, and humidity. The likelihood of air pollution and its negative health effects will probably decrease as economic conditions improve. The literature review shows indoor air pollution is important to human health. However, in the case of Pakistan, especially the Multan district, the study analyses indoor air pollution's impact on human health. Therefore, this study examines the impact of IAP on human health in Multan district, Pakistan in addition to indoor air pollution, socio-demographic variables have also been considered as a factor of human health. So this study will contribute tithe literature significantly by providing the impacts of IAP on human health.

3. Data and Methodology

To analyze the impact of indoor air pollution on health outcomes, data from 400 households have been collected from the Multan district using a convenient sampling technique. IAP has been measured by using an air quality meter. The $PM_{2.5}$readings was used to describe indoor pollutant levels. Particulate matter (PM) usually forms in the atmosphere due to chemical reactions between different pollutants. The particles' penetration closely depends on their size (Wilson & Suh, 1997). The air quality meter was installed for two hours in each household to get $PM_{2.5}$readings. $PM_{2.5}$readingsabove 35 $\mu g/m^3$are considered unhealthy and can cause serious health issues (EPA, 2022)[1]. Households where $PM_{2.5}$ readings greater than 35 were considered indoor air polluted houses, while $PM_{2.5}$ readings less than 35 have evidence of no indoor air pollution. The value one was assigned to indoor air-polluted houses, while the value zero was assigned to houses with no indoor air pollution. Health outcomes have been measured using physical health symptoms such as ear, nose and throat infections, respiratory issues, coughing,

[1] https://www.epa.gov/criteria-air-pollutants/naaqs-table

sleeping disorder, headache, and reduced energy levels. Similarly, behavioral health symptoms have been measured using symptoms such as depression, aggressiveness, walking faster, and aggressiveness during cold and hot days. The average response of these indicators has been used as physical and behavioral health symptoms. The PHI and BHI values range from 0 to 1, and a value closer to one indicates a high level of symptoms in a household. In addition, environmental concern and environmental awareness were also utilized as health factors and measured using a 5-point Likert scale containing four items, as used by Lounsbury and Tornatzky (1977), and Noordin and Sulaiman (2010), respectively. Cronbach's alpha has been used to measure the data reliability of EC and EA. The Cronbach's alpha value should be greater than 0.70, and it has been found that the value of EC and EA is 0.703 and 0.737, respectively, which suggests that the data of EC and EA is reliable. Household demographic factors are also important in influencing health outcomes, so the variables area of residence, household size, household head age, education, and household income have also been considered as a factor of health outcomes. An Ordinary Least Square (OLS) method has been applied to analyze the impact of IAP on health outcomes. Two models are developed to analyze the impact of IAP on health outcomes.

Model 1: Estimates the Impact of IAP on Physical Health Symptoms

$$PHI = \beta_o + \beta_1 AREA + \beta_2 HHA + \beta_3 HHE + \beta_4 HHS + \beta_5 HHI + \beta_6 IAP + \beta_7 EC + \beta_8 EA + \beta_9 ACD + u \quad (1)$$

Model 2: Estimates the Impact of IAP on Behavioral Health Symptoms

$$BHI = \beta_o + \beta_1 AREA + \beta_2 HHA + \beta_3 HHE + \beta_4 HHS + \beta_5 HHI + \beta_6 IAP + \beta_7 EC + \beta_8 EA + u \quad (2)$$

The description of variables is given in Table 1.

Table 1: Description of Variables

Variable	Description of Variables	
Dependent Variable		
PHI	Physical Health Index	Average of different symptoms related to physical health
BHI	Behavioral Health Index	Average of different symptoms related to behavioral health
Independent Variables		
AREA	Area of residence	= 1 if Urban = 0 if Rural
HHA	Household head age	Years
HHE	Household head education	Completed years of schooling
HHS	Household size	Number of members in a household
HHI	Household income	Nature log of monthly income in RS
IAP	Indoor air pollution ($PM_{2.5}$)	= 1 if $PM_{2.5}$ is greater than 35μg/m^3 = 0 if $PM_{2.5}$ is less than 35μg/m^3
EC	Environmental concern	Measured with a 5-point Lickert scale
EA	Environmental Awareness	Measured with a 5-point Lickert scale
ACD	Use of air cleaning device	= 1 if Yes = 0 if No

4. Data Analysis

The descriptive statistics of variables in terms of minimum value, maximum value, mean, standard deviation, skewness, and kurtosis have been reported in Table 2. The results show that the minimum value of $PM_{2.5}$ is 13, maximum value is 240, mean $PM_{2.5}$is 68.78, standard deviation is 61.72, skewness is 1.908, which illustrates the positively skewed distribution, and kurtosis value 3.799 illustrates the distribution is leptokurtic. We can also observe the descriptive statistics of variables from Table 2 similarly.

Table 2: Descriptive Statistics

	Minimum	Maximum	Mean	S.D.	Skewness	Kurtosis
$PM_{2.5}$	13	340	68.78	61.72	1.908	3.799
PHI	0.00	1.00	0.36	0.21	0.32	2.69
BHI	0.00	1.00	0.42	0.30	0.33	2.00
AREA	0.00	1.00	0.59	0.49	-0.35	1.12
HHA	22.00	90.00	46.75	12.74	0.29	2.85
HHE	0.00	18.00	9.97	4.33	-0.35	2.51
HHS	2.00	19.00	6.64	2.84	1.67	6.63

HHI	9.47	13.14	10.85	0.67	0.41	3.13
EC	7.00	20.00	15.84	3.28	-0.82	2.78
EA	8.00	25.00	18.89	3.94	-0.82	2.96
IAP	0.00	1.00	0.52	0.50	-0.08	1.01

Source: Author's Calculations

Correlation matrix estimates the degree of association between variables. The outcomes of the correlation matrix have been reported in Table 3. The results show that physical health outcomes are positively correlated to the household size (0.158) and indoor air pollution (0.583), while physical health symptoms negatively correlated to the area (-0.134), household head age (-0.184), household head education (-0.346), household income (-0.419), environmental concern (-0.489), and environmental awareness (-0.473). Similarly, behavioral health outcomes are positively correlated to household size (0.079) and indoor air pollution (0.626), while behavioral health symptoms negatively correlated to the area (-0.140), household head age (-0.133), household head education (-0.632), household income (-0.618), environmental concern (-0.532), and environmental awareness (-0.556).

Table 3: Correlation Matrix

	PHI	BHI	AREA	HHA	HHE	HHS	HHI	EC	EA	IAP
PHI	1.000									
BHI	0.448	1.000								
AREA	-0.134	-0.140	1.000							
HHA	-0.184	-0.133	0.015	1.000						
HHE	-0.346	-0.632	0.127	0.157	1.000					
HHS	0.158	0.079	0.006	0.336	0.012	1.000				
HHI	-0.419	-0.618	0.239	0.346	0.570	0.252	1.000			
EC	-0.489	-0.532	0.142	0.195	0.307	-0.155	0.479	1.000		
EA	-0.473	-0.556	0.173	0.175	0.351	-0.152	0.494	0.570	1.000	
IAP	0.583	0.626	-0.139	-0.233	-0.469	0.159	-0.592	-0.686	-0.713	1.000

Source: Author's Calculations

To analyze the influence of IAP on health outcomes, an ordinary least square model has been applied to the data. The outcomes are reported in Table 4. Health symptoms have been measured using the physical and behavioral health indexes. The results found that household head age, household size, household income, indoor air pollution, environmental concern, and air cleaning device have been the significant factors of physical health symptoms, while the variables household head age, education, household income, indoor air pollution, environmental concern, and environmental awareness have been the significant factors of behavioral health symptoms. The significance of the models has been evaluated using F-statistic, which points out that both models are overall statistically significant. Likewise, the model's goodness of fit has been assessed using R^2. The R^2 of model-I points out that explanatory variables explain 40.62 percent of changes in the PHI, while the remaining 59.38 percent is due to other factors.

Table 4: Indoor Air Pollution and Health Outcomes

	Model 1 DV: Physical Health Index		Model 2 DV: Behavioral Health Index	
Variables	Coefficient	t-Statistic	Coefficient	t-Statistic
C	0.8991	4.4404*	2.1168	9.2845*
AREA	-0.0035	-0.2023	0.0158	0.8009
HHA	-0.0012	-1.7451***	0.0016	1.9546***
HHE	-0.0031	-1.2887	-0.0240	-8.8410*
HHS	0.0090	2.5252**	0.0061	1.5236
HHI	-0.0346	-1.7371***	-0.1103	-4.9114*
IAP	0.1171	3.8825*	0.0672	2.0039**
EC	-0.0070	-1.9524***	-0.0132	-3.2633*
EA	-0.0027	-0.8711	-0.0114	-3.2544*
ACD	-0.0814	-4.1387*	--	--
R^2	0.4062		0.6030	
Adjusted R^2	0.3925		0.5949	
F-statistic	29.6518		74.2565	
Prob.	0.0000		0.0000	
N	400		400	

Source: Author's Calculations**,** * Level of Significance at 1%, ** Level of Significance at 5%, *** Level of Significance at 10%

The R^2 of model-II point out those explanatory variables explain 60.30 percent of changes in the BHI, while the remaining 39.70 percent is due to other factors. Considering first the role of household head age in influencing health symptoms, it has been found that HHA is negatively and significantly related to physical health symptoms. It implies that with the increase in age of the household head, their skills and experiences increase, so they earn a high income and invest more in the health of their family members. But HHA has been positively related to behavioral health symptoms. It implies that older household heads have more chances to have depression, anxiety, and aggressiveness, which negatively influences the household's psychological or behavioral health (McKinnon, Holloway, Santoro, May, & Cronan, 2016). Similarly, the education level of the household head has been found to be negatively related to physical and behavioral health symptoms. The coefficient of HHE exhibits that as HHE increase by one unit, the BHI also increases by -0.0240 units. It implies that education helps people to acquire a variety of abilities and characteristics (such as cognitive and problem-solving skills, learnt effectiveness, and personal control) that incline them to better health outcomes (Mirowsky & Ross, 2005). These results were also reported by (2020); Zajacova and Lawrence (2018). Household size has been turn out to be negatively associated to physical health symptoms. The coefficient of HHS exhibits that as HHS increase by one unit, the PHI also increases by 0.0090 units. It implies that an increase in household size required more food and cooking hours in a house; it enhances indoor pollution and deteriorates the members' physical health.

Economic status of the households is also essential in determining the health status of the household. It has been found that household income is a discouraging factor in physical and behavioral health symptoms. The coefficient of HHI exhibits that as HHI increases by one unit, the PHI and BHI decline by -0.0346 and -0.1103 units, respectively. It suggests that households with higher income levels are more likely to reside in areas with improved physical infrastructures and healthcare facilities. Moreover, households with greater income levels typically have more leisure time, allowing them to engage in social activities and sustain positive relationships (L. Chen, Gong, & Yuan, 2022). These outcomes were also found by (L. Chen et al., 2022; Deaton, 2008). IAP is more harmful and poses greater health hazards because of long indoor exposure to air pollutants (Rahman, 2004). IAP has been found to be deteriorating the physical and behavioral health of households. The coefficient of IAP exhibits that as IAP increases by one unit, the PHI and BHI increase by 0.1171 and 0.0672 units. IAP causes an increased risk of several serious conditions, such as chronic respiratory disease, lung cancer, low birth weight, pneumonia, stroke, asthma, and cataracts in adults and children (Bruce, Perez-Padilla, & Albalak, 2002). These results were also confirmed by (Ipek & Ipek, 2021; Kim et al., 2018).

Environmental concern and awareness are important to improve the environmental condition of the house, and it also influences the health of the individuals in a house. The results showed that environmental concern is negatively and significantly related with physical and behavioral health symptoms. The coefficient of EC suggests that as EC increases by one unit, the PHI, and BHI lead to a decline of -0.0070 and -0.0132 units, respectively. Similarly, environmental awareness has been found to be a negative and significant factor in behavioral health symptoms. The coefficient of EA suggests that as EA increases by one unit, the BHI leads to a decline by -0.0114 units. It implies that a lack of environmental concern and awareness can increase the risk of diseases, including cancer, heart disease, and asthma (Resnik, 2008). Lastly, the variable air cleaning device has been negatively and significantly associated with physical health outcomes. The coefficient of ACD suggests that as ACD increases by one unit, the BHI leads to a decline by -0.0814 units. It implies that a better-ventilated system in a house reduces IAP and improves the physical health of the households (Ipek & Ipek, 2021).

5. Conclusions and Recommendations

This study endeavors to investigate the impact of indoor air pollution on health outcomes in Pakistan. For this purpose, the data of 400 households have been collected from the Multan district using a convenient sampling technique. Indoor air pollution was measured using $PM_{2.5}$. The study found that indoor air pollution has significantly impacted physical and behavioral health symptoms. The study also found that household head age, household size, household income, environmental concern, and air cleaning device have been the significant factors of physical health symptoms, while the variables household head age, education, household income, environmental concern, and environmental awareness have been the significant factors of behavioral health symptoms. Considering the study outcomes, it is concluded that poor indoor air quality enhances a household's physical and behavioral health symptoms. So efforts should be made to improve indoor air quality by improving the house and kitchen structure using better building materials and high-roofed kitchens. Improvement in the ventilation system and keeping all doors and windows open during the cooking period can help improve the indoor air quality and hence health status of the household. Better socioeconomic status is also beneficial to improve IAQ and health, so it is advised that employment opportunities for poor people should be ensured to switch to clean fuel for cooking and better health. Lastly, environmental awareness and its relationship with human health should be increased using social media and TV platforms. The study has some important limitations. First, the data of households of the Multan district has been used in a study, the same study can also be enhanced by using larger datasets in Pakistan. Secondly, indoor air pollution has been measured using $PM_{2.5}$, so future studies can also be designed by measuring PM_{10}, SO_2, and O_3 etc. Lastly, health outcomes have been measured using self-rated questionnaire. Although self-rated questionnaire is widely used technique to find the health status of individuals, but there can be a difference between self-rated health status and actual health status of the respondents. So, the results can be ambiguous in some extent due to this discrepancy.

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