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Research Paper

Policy Gaps and Health Risks: Addressing Women's Indoor Air Pollution Exposure in Pakistan

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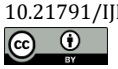

Abstract. Indoor air pollution currently poses a significant challenge, adversely impacting both the physical and mental health of women. The substantial use of fossil fuels for domestic chores endangers women's health and exposes them to considerable risks. In this regard, this study elucidates the factors driving the use of fossil fuels in domestic kitchens in Pakistan. The association between primary indicators such as women's health, duration of women's current pregnancy, and pregnancy status with household air pollution is analyzed. We use Ordinary Least Squares (OLS) regression in Stata, and the results indicate that the type of cooking fuel significantly affects women's health. Furthermore, indoor cooking also negatively influences the duration of pregnancy. Based on these results, the paper provides practical policy recommendations for governments and policymakers to mitigate health risks. This study is instrumental in analyzing the current state of household air pollution, offering a robust model for countries heavily reliant on fossil fuels, and examining the consequent health impacts on women.

Keywords: Indoor Air Pollution; Cooking Practices; Women; Pregnancy Complications.

Introduction

Indoor air pollution is now a major issue, especially for developing countries, which causes high infant and adult mortality rates. Similar to outdoor air pollution, which affects the ecological and anthropological aspects of the globe, it leads to the deterioration of biodiversity. As per the World Health Organization (WHO) report, air pollution claims more than seven (7) million lives annually. Moreover, millions suffer from chronic diseases, i.e., respiratory diseases, cardiovascular diseases, strokes, etc. [1].

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From the perspective of indoor air pollution, it has caused the premature demise of around five (5) million persons annually. Here, World Bank (WB) data states that the significant indoor pollutants are coal, wood, crops, straw, and animal dung [2]. In South Asia, reliance on polluting cooking fuels remains common, and women experience the highest exposure because they spend more time near household cooking activities [3]. This study, therefore, focuses on Pakistan, where household cooking practices and limited ventilation make household air pollution an important and preventable risk to women's health.

In the contemporary world, developing nations are more concerned about renewable energy resources for sustainable development. However, in Pakistan, such resources are yet to be explored. Thus, Pakistan mostly relies on non-renewable resources, such as coal, gas, and oil, to power both households and industry. As a byproduct of the utility of fossil fuels, the country is marred by environmental and health issues. From the perspective of household management, the majority of the country's population suffers from substandard environmental and health conditions. The use of fossil fuels in households with insufficient ventilation increases these risks for families. Thus, domestic pollution from culinary activities, along with extended time spent inside the house, causes a variety of diseases among women in Pakistan [4].

Prior studies have focused on the impacts of fossil fuels on environmental issues, renewable energy, etc. However, the idea of increasing indoor pollution and its association with women's health, specifically pregnant women's health, has been largely understudied. Since domestic cooking techniques have altered in the contemporary world, developing countries still face the issue, as power supply remains insufficient. Regarding this, Pakistan suffers from the use of fossil fuels in domestic kitchens, which is attributed to several factors. 1- The price of sustainable fuels is very high, 2- most of the population lives in rural areas where the infrastructure lacks alternative resources, and 3- the interior of the house does not provide sufficient ventilation. Thus, Women in such houses are prone to health risks that require immediate attention and remedial measures to undo the peril [5].

With this backdrop, we focus on household air pollution (HAP), which arises from indoor emissions from cooking, particularly when households rely on solid fuels such as biomass, coal, gas, and oil. HAP is conceptually distinct from ambient (outdoor) air pollution, which is driven largely by transport, industry, and regional atmospheric processes [6]. Our exposure measure captures primary household cooking fuel type, which serves as a proxy for indoor combustion-related exposure pathways, rather than ambient outdoor pollution. This study addresses the above-mentioned issues and contributes in the following ways. First, it demonstrates how fossil fuels have been widely employed in Pakistan over the last two decades, leading to thousands of fatalities. Second, this study statistically examines the impact of regular indoor smoking on women's health. We used Stata and the ordinary least squares (OLS) approach to examine the statistical relationship between home air pollution and a range of women's health markers. The research focused on particular topics such as pregnancy and fertility. Finally, the research also adds to the current literature by highlighting Pakistan's increased consumption of fossil fuels. Finally, the paper offers policy recommendations, urging governments and stakeholders to take immediate action and explore feasible ways to mitigate the negative impacts of this cooking method. The empirical analysis is restricted to Pakistan, using the 2017 to 2018 DHS household survey, and all results and policy implications are interpreted in the Pakistan context.

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1. Literature Review

Energy plays a vital role in bolstering economic growth, improving the quality of life, while augmenting household and industry. The optimal use of energy contributes to improving air quality and the environment, as well as mitigating the health hazards [7], [8], [9]. However, the non-renewable energy sources, coal, wood, dung and other contaminated fossil fuels, are required for cooking [10] at large, are considered dangerous to health as household air pollutants [11], [12]. Statistics demonstrate that approximately 3.8 million people have lost their lives globally due to the utilization of such fuels. In Asia, approximately 0.5 million people lost their lives due to household air pollution. In addition, numerous individuals suffer from respiratory ailments such as lung cancer, asthma, and heart attacks, which are not only detrimental to their well-being but also diminish the quality of life of otherwise healthy people.

Energy consumption is also associated with the deterioration of the ambient environment. The combustion of fossil fuels releases harmful substances, including carbon dioxide (CO2), carbon monoxide, and particulate matter (PM2.5), into the atmosphere [13]. Here, the use of biomass fuels for cooking purposes also increases the ratio of outdoor air pollution [14]. The study suggests that around 3 billion people use fossil fuels for cooking purposes [15]. The majority of people living in low-income countries and developing nations regularly consume fossil fuels. Most cooking is indoors, often without adequate ventilation, leading to significant levels of harmful air pollution in the household. Lack of electricity is another factor contributing to the prevalence of respiratory diseases, such as tuberculosis, because many people in developing countries resort to burning kerosene for lighting [16], [17].

Household air pollution has severe consequences for physical and mental health [18]. Women and children are more affected by indoor air pollution. Household air pollution affects women's fertility and mortality. Furthermore, fossil fuels not only affect women’s ability to get pregnant but also affect the physical development of a child and the risk of birth defects [19], [20].

The previous studies discussed the health implications related to respiratory diseases such as asthma, heart attack [21], and lung cancer [22]. The studies also examined the relationship between physical health [23], cardiovascular health diseases [24], causes of disability [25] as well as energy poverty issues due to mental sickness in children [26], [27]. These recent studies show the intensity of ambient air pollution; however, the adverse impacts of fossil fuels in domestic kitchens, i.e., homes, have been overlooked. In this regard, women’s fertility and pregnancy issues need urgent attention, as women are the primary group to cook food and stay at home in South Asia. Our study highlights a critical problem and provides a detailed analysis of indoor air pollution in Pakistan. It is imperative to understand the increasing consumption of fossil fuels in Pakistan and the impact of household air pollution on women’s health.

Recent research highlights the ongoing public health burden of indoor air pollution beyond traditional respiratory outcomes. A 2024 systematic meta-analysis found that exposure to household air pollution from biomass fuels significantly increases the risk of adverse pregnancy outcomes, including low birth weight, preterm birth, small-for-gestational age, and stillbirth, particularly in low- and middle-income countries where solid fuels are predominantly used [28].

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Emerging evidence also demonstrates broader health impacts on women beyond birth outcomes. A large 2025 study conducted among women in Nepal showed that use of solid and non-clean cooking fuels was associated with increased risks of anemia, depression, and anxiety, suggesting that household air pollution adversely affects both physical and mental health [29]

In addition, recent literature on prenatal pollutant exposure highlights potential long-term effects on child health. Systematic evidence indicates that prenatal exposure to fine particulate matter and other pollutants is linked to increased susceptibility to lower respiratory tract infections and impaired respiratory development in childhood and adolescence [30]. Global analyses also argue that high particulate matter levels contribute to premature birth and low birthweight on a large scale, which can have lasting implications for child survival and cognitive development [31]

Together, these findings underscore the multifaceted health consequences of indoor air pollution and the importance of addressing both immediate reproductive outcomes and potential long-term health impacts.

2. Methods and Data

In this study, we used a dataset obtained from the United States Agency for International Development (USAID), which conducts surveys across various regions, including Asia and Africa, in partnership with local governments. The dataset we used, DHS-VII 2017-18, was collected with formal approval and includes a wide range of household-level variables, such as cooking fuel type, cooking location, kitchen separation, and indoor smoking behaviors [32]. The data also provides detailed demographic information, particularly health indicators for women, such as pregnancy status and mortality.

Our analysis focused on four main variables: cooking fuel type, cooking location, presence of a separate kitchen, and indoor smoking. We chose these because they are closely tied to household air pollution, a major health risk for women. Cooking fuel was selected because it directly impacts indoor air quality. The use of polluting fuels like biomass and coal is known to increase indoor pollution, which can lead to respiratory diseases, cardiovascular issues, and complications during pregnancy. A cooking place is important because indoor cooking exposes women to pollutants for longer periods. Ventilation is another key factor that reduces harmful air pollution, and poor ventilation increases the health risks. Indoor smoking is a significant source of indoor pollution, and its effects on respiratory health and pregnancy complications are well-documented. These factors are modifiable, making them central to our study's goal of identifying actionable health risks.

We also recognize that other factors, such as maternal age, household wealth, parity, and access to prenatal care, could influence women’s health outcomes. However, our study focused specifically on environmental exposures related to household air pollution, which are modifiable through public health interventions. We didn’t include these other factors in our model because they were not available in the dataset. We acknowledge that omitting them could introduce omitted-variable bias, which we discuss in the limitations section of the manuscript. Future studies could address this by including these variables to provide a more comprehensive understanding of women’s health.

To assess women’s health, we considered both demographic and health indicators, with the duration of pregnancy as a primary outcome variable. Specifically, the duration of the current pregnancy (V214)

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was measured in months for women who were currently pregnant (V213 = 1). We analyzed data from about 14,000 households in Pakistan to estimate associations between household air pollution and women's health outcomes using Ordinary Least Squares (OLS) regression models. Since this is an observational study, we caution against interpreting the coefficients as causal effects, given the potential for unobserved confounding and measurement limitations. Therefore, the results should be considered as correlational, and we discuss the policy implications with this in mind.

For key variables, we used the following coding scheme: 1 = LPG (clean fuel), 2 = wood (biomass fuel), 3 = biomass (e.g., crop waste), 4 = coal/charcoal (polluting fuel) for cooking fuel, 0 = inside the house, 1 = separate building for cooking place, and 0 = No, 1 = Yes for indoor smoking.

To ensure the robustness of our regression models, we tested for key OLS assumptions. We checked homoscedasticity using the Breusch-Pagan test, which showed no significant violations. We evaluated the normality of residuals using the Shapiro-Wilk test, and the residuals were approximately normal. Finally, we assessed multicollinearity using Variance Inflation Factors (VIFs), and no issues were detected, as all VIFs were below the threshold of 10, indicating no concern about multicollinearity.

Independent Variable	**Household Indoor Pollution**	**Items**	**Explanation**
		HV226	Type of cooking fuel
		HV241	Food cooked in the house/separate building/ outdoors
		HV242	The household has a separate room used as a kitchen
		HV252	Frequency household members smoke inside the house
Dependent Variable	**Health**	HV219	Sex of head of household
		HV025	Type of place of residence
		V717	Respondent's occupation (grouped)
		V106	Highest educational level
		V213	Currently pregnant
		V228	Ever had a terminated pregnancy

Table 1. Description of Variables

Variables	**Mean**	**S. D**
Type of cooking fuel	5.13	4.80
Food cooked in the house/separate building/ outdoors	2.2	.70
The household has a separate room used as a kitchen	.46	.51
Frequency household members smoke inside the house	.40	.661
Sex of head of household	1.16	.310
Type of place of residence	1.20	.376
Respondent's occupation (grouped)	1.22	3.45
Highest educational level (grouped)	0.98	.864
Currently pregnant	.022	.198
Ever had a terminated pregnancy	.21	.439

Table 2. Statistical Summary

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3. Results

Figure 1 shows the results of the type of cooking fuel used in each country. In Pakistan, 45% of households use wood and 48% use LPG or natural gas for cooking. Burning wood for cooking purposes is associated with higher pollution levels, which can affect women's health.

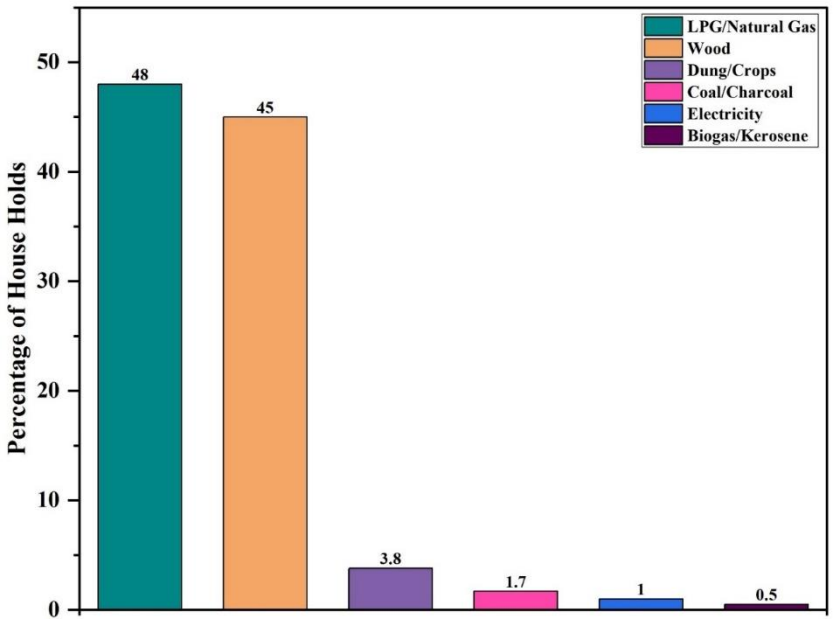

Figure 1. Type of cooking fuel

Figure 2 presents the distribution of cooking locations. The results indicate that approximately 92% of households in Pakistan cook indoors. Indoor smoking is associated with increased levels of household air pollution. Figure 3 shows the prevalence of smoking inside the home in Pakistan. Approximately 29% of households report indoor smoking every day, which can further increase indoor pollutant levels and associated health risks.

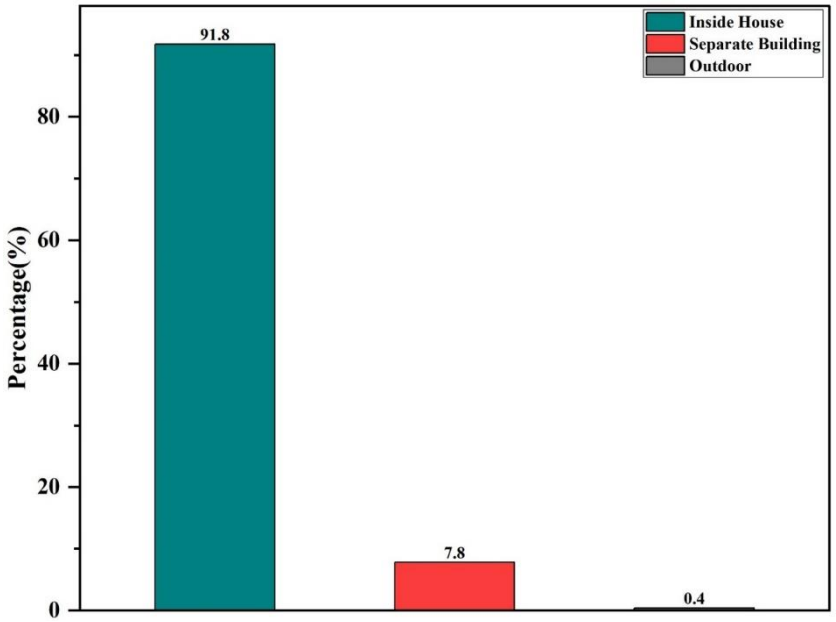

Figure 2. Place of cooking

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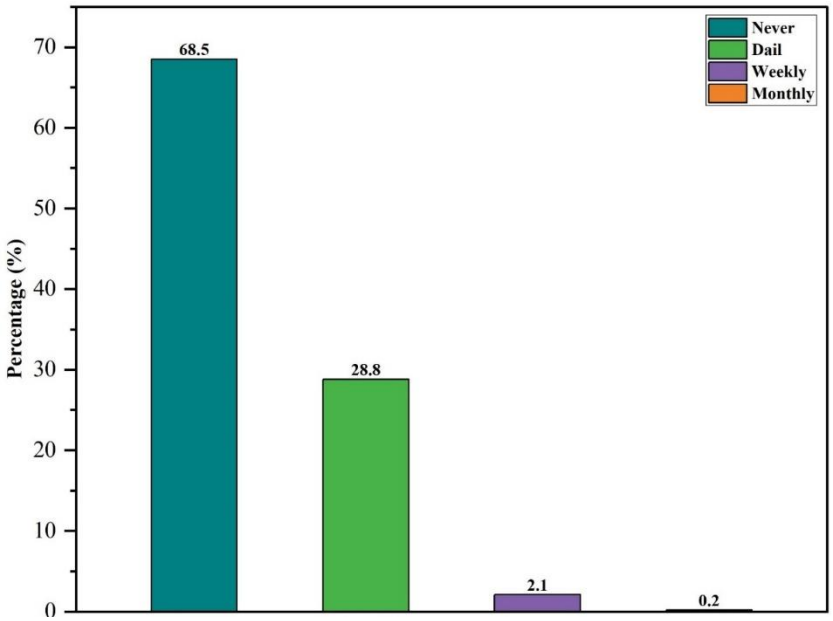

Figure 3. Rates of indoor smoking

Table 3 reports the results of the analysis of the relationship between household air pollution indicators and women's health outcomes, estimated using Ordinary Least Squares (OLS) regression in Stata.

Model 1: Coefficients for Models with 'Currently Pregnant' as the Outcome		
Explanatory Variables	**Coefficient**	**t-Statistic**
Cooking Fuel		
Female	-0.054	(-0.97)
Cooking Place		
Rural	-0.090	(0.003)
Occupation		
Professional/technical/managerial	0.254**	(3.08)
Education		
Primary	0.045*	(1.65)
Currently Pregnant		
Women who are pregnant	-0.095	(-0.39)
Model 2: Coefficients for Models with 'Ever Had a Terminated Pregnancy' as the Outcome		
Explanatory Variables	**Coefficient**	**t-Statistic**
Cooking Fuel		
Female	-0.015	(-0.43)
Cooking Place		
Rural	-0.072**	(-3.79)
Occupation		
Agricultural - self-employed	-0.100	(-1.08)
Education		
Primary	0.092**	(2.09)
Terminated Pregnancy		
Women who have had a terminated pregnancy	0.004	(0.23)

***Significant at the level 0.01, **Significant at the level 0.05, *Significant at the level 0.1.

Table 3. Results of indoor pollution in Pakistan

In Pakistan, household cooking practices and indoor exposure conditions indicate substantial health risks for women, particularly where polluting cooking fuels are used, and ventilation is inadequate. The poorly ventilated system and smoke from inefficient cookstoves also raise serious questions. Carbon

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emissions not only harm health but also contribute significantly to climate change [33]. The use of traditional sources of non-renewable energy produces high emissions, and in line with other studies, the findings of this study also suggest that pollution from burning animal dung, straws, and agricultural waste affects the environment in South Asia [35].

Discussion

We tested the relationship between household air pollution and women's health in this study. Our analysis revealed a strong association between indoor air pollution and several health outcomes, particularly those related to cooking fuel type and cooking location. Specifically, the cooking fuel type and the location where food is prepared were positively associated with respondents' occupation (professional or technical) and education (primary level). On the other hand, indoor smoking was more commonly seen in agricultural self-employed occupations. Notably, indoor smoking was found to significantly impact pregnancy, contributing to higher rates of termination and miscarriage. Furthermore, our results showed that cooking location and ventilation were negatively associated with rural residence. Poor ventilation was also associated with occupations in the services sector.

Despite these findings, the impact of cooking fuel type, place of cooking, ventilation, and indoor smoking on pregnant women was not significant. However, we did find that indoor smoking was linked to an increased risk of terminated pregnancies in women in Pakistan. Interestingly, although around 68% of Pakistan's population does not smoke indoors, a significant number still report indoor smoking. Smoking is widely known to cause illness and disability, harming internal organs. Indoor smoking worsens these risks, contributing to complications during pregnancy. Additionally, with 45% of households in Pakistan still relying on firewood for cooking in poorly ventilated spaces, many women are exposed to indoor air pollution from inefficient cooking methods, which leads to adverse pregnancy outcomes.

Our findings reinforce the harmful effects of using non-renewable cooking fuels and cooking in poorly ventilated areas. These results are consistent with the situation in Pakistan, where indoor air pollution from such sources severely impacts women's health. This is particularly concerning because many women cook in the same spaces where they live, which further worsens the risks. Using poorly ventilated cooking systems only adds to the negative health consequences for women.

As noted earlier, fossil fuel use is the main source of household air pollution, and inadequate cooking spaces contribute to the ongoing health crisis. This study highlights the need to prioritize women's health in policy development. A large portion of the population cannot afford modern cookstoves or homes with proper ventilation systems, leaving them vulnerable to outdated and hazardous cooking methods. Furthermore, the lack of awareness, poverty, and a weak economic system compound these challenges. In rural areas, many people do not fully understand the health risks posed by fossil fuels, leading to continued exposure [36]

Recent studies show that household air pollution extends far beyond reproductive health concerns, affecting broader aspects of health. For instance, a multi-city study published in 2025 found that even natural gas, often seen as a cleaner fuel, was linked to an increased risk of COVID-19 infection in both children and adults [37]. This suggests that some fuels, even those considered cleaner, can still increase

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respiratory vulnerability and the risk of infection. These findings highlight that household air pollution is not just a concern for pregnant women, but for entire families. Policy measures should address both immediate health risks and the long-term effects of exposure.

Moreover, research published by Puzzolo et al. (2024) supports the idea that even natural gas, typically regarded as a safer cooking fuel, is linked to increased respiratory issues and other health complications in both children and adults. This indicates that public health policies should not only address the immediate risks of exposure but also the long-term effects of household air pollution from various types of cooking fuels. Further studies also suggest that prenatal exposure to indoor air pollution can increase the likelihood of respiratory issues in children, negatively affecting their development and cognitive outcomes [38].

These findings underscore the importance of considering both immediate and long-term health risks when designing policies to reduce household air pollution. The complexity of this issue, which includes both reproductive and broader health outcomes, must be fully acknowledged in any public health initiative addressing indoor air pollution.

A key limitation of our study is its cross-sectional design, which prevents us from establishing causal relationships between household air pollution and women's health outcomes. While our study identifies significant associations between factors such as indoor smoking and cooking fuel use and women's health, these findings should be interpreted as correlational rather than causal. The cross-sectional data allow us to infer relationships, but not causality. To better understand the causal pathways, further research using longitudinal or experimental designs is needed.

Conclusion and Policy Suggestions

This study utilized individual datasets to examine the effects of rising household energy consumption, particularly in cooking activities, on women's health in Pakistan. The findings indicate that the types of cooking fuels, cooking locations, ventilation systems, and indoor smoking significantly influence various health indicators for women. Given that women are the primary caregivers and often the main cooks for their families in these regions, indoor air pollution poses a serious health risk in the absence of efficient cookstoves and cleaner energy sources.

The situation is further exacerbated by growing populations, dependence on fossil fuels, ignorance, low educational levels, and a lack of technical innovation, which aggravate the economic and political conditions. The study's conclusions have significant implications for stakeholders and policymakers on both theoretical and practical levels. The findings indicate that these nations exhibit comparatively high rates of indoor smoking and fossil fuel consumption. This demonstrates a widespread lack of awareness or understanding of the health implications, underscoring the need for education and awareness campaigns to address the harmful effects of chemical pollutants on human health.

Governments should invest in advancing renewable energy technologies and encourage the use of efficient energy sources, such as solar or electric cookers, especially in rural regions, to cut fossil fuel consumption. Reducing dependence on crops, firewood, and animal waste will eventually lead to lower carbon emissions. A plan for shifting the energy system toward cleaner alternatives is crucial to safeguard public health and the environment. The findings also emphasize that poor ventilation creates

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major health hazards, particularly for disadvantaged communities unable to afford modern, energy-efficient housing. Thus, government initiatives must focus on rural zones and bolster the rural economy to tackle these challenges effectively.

Additionally, health issues are further exacerbated by the lack of essential facilities, such as electricity, clean water, and hospitals, for rural residents. The acquisition of modern cooking stoves remains challenging and costly for the majority of low-income individuals. Therefore, the government should implement programs that promote the use of efficient cookstoves and reduce associated taxes. Through these initiatives, the government can also raise public awareness, which is crucial for understanding the severity of hazardous pollutants and their health impacts.

Author Contributions

Nargis Habib: Conceptualization; Formal analysis; Methodology; Software; Visualization; Roles/Writing - original draft, Writing - review & editing. **Sehrish Habib;** Resources; Writing - review & editing, Data curation. **Mehreen Hassan;** Writing - review & editing, Visualization, Methodology, Data curation. **Ahsan Shafi:** Writing - review & editing, Visualization, Methodology. **Muhammad Haseeb Nawaz**: Writing - review & editing, Funding acquisition; Supervision; Validation; Investigation; Project administration.

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Conflict of Interest

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.

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