

Indoor Air Pollution and Concerned Health Costs in Indian Context



Unmilan Kalita, Arup Kumar Hazarika

Abstract: Clean air is considered the fountain of life that enables humankind to sustain healthy lives while supporting unique ecosystems of the Earth. The United Nations, being the supreme policymaking body in the world, has duly stated that “clean air is a human right”. The underlying reason for this derives itself from gruesome statistics asserting that between 6 and 7 million people die prematurely each year due to air pollution, and around 90% of the global pollution breathes polluted air. Being the existential threat pollution is, most of it is caused by burning of fossil fuels that contributes not only to climate change but also deteriorating human health. A significant portion of air pollution is constituted by indoor air pollution through carbon dioxide (CO₂) emissions, which has been a major cause of concern for India. It has been observed that 9 out of 10 people in India breathe air that breached safe limits and 7 million people die each year due to household air pollution through exposure to fine particles causing cardiovascular diseases, lung cancer and other pulmonary diseases. Women form a significant portion of such sufferers, whereby, a WHO report has found that mothers were more likely to deliver underweight babies in households with indoor air pollution from solid fuels. Associated with this, is the issue of increasing household expenditure on health vis-à-vis women. This paper examines the impact of such indoor pollution on women vis-à-vis health costs as part of their household expenditure allocations. Observations emphasise the need to reverse such trend of increasing indoor air pollution while moving on to a phase of employing greener fuels and technologies among households, and associated sensitive policymaking. This is expected to not only increase the standard of health among women of different strata but also will propel the productivity of human capital on a per capita basis.

Keywords: air pollution, women, health costs, carbon emissions.

I. INTRODUCTION

It cannot be dismissed as an erroneous statement when one calls air and water, the two most essential substances on which the existence of all life rests, as “global garbage cans”.

Manuscript published on 30 September 2019

* Correspondence Author

Unmilan Kalita, Department of Economics, Gauhati University, Assam, India. Email: unmilan.k@gmail.com

Arup Kumar Hazarika, Department of Zoology, Cotton University, Assam, India. Email: cheifeditorclarion@gmail.com

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](https://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

In regard to contamination of breathable air, household or indoor air pollution (IAP) today is considered as one of the most life-threatening conditions for humanity. It is a hardened fact that more than two billion people depend on dirty fuels globally to fulfil energy needs.

Dirty fuels attribute their dirtiness to a significant amount of carbon and particulate matter generated on their combustion, and they include mostly solid fuels (coal, firewood), fossil fuels, kerosene and so on [1].

Combustion of carbon intensive fuels in traditional cooking arrangements such as open fires and *chulhas* (stoves) has empirically resulted in high incidence of IAP [2]. In 2016, 2.6 million people died premature deaths with diseases resulting from IAP, witnessed predominantly in women and children. India faces a similar burden of morbidity and mortality with 4.8 lakh deaths due to IAP in 2017. In general, it has been observed that India’s average life expectancy would be 1.7 years higher if air pollution is contained within minimal standards.

Women and children have been the worst sufferers of IAP due to their spending of more time in household environments. Reports suggest that more than 80% of rural and 20% of urban households use solid fuels for cooking. Additionally, the nature of Indian food requires long cooking hours that produce large amounts of oil vapour and particulate matter. As a consequence, a WHO report observed smoke levels in lungs of females showing an average reading of 7.77 ppm of carbon monoxide, suggesting levels that otherwise would result from smoking about ten cigarettes a day. This invariably results in greater incidence of respiratory diseases and a correlated rise in household out-of-pocket healthcare expenditure. The economic cost from this has been estimated to be almost 1.5% of India’s GDP compared to its spending of a mere 1.4% on healthcare.

The purpose of this paper is to discuss and analyse the impact of IAP on women vis-à-vis health costs, in the context of India. It should be noted that India has a huge geographical and cultural diversity, and differences in levels of IAP due to cooking may vary widely across different states. However, it cannot be denied that IAP is a global issue and deserves significant attention. This paper includes an analysis of the IAP scenario in India and its associated disease burden vis-à-vis chronic obstructive pulmonary disease (COPD) and asthma. These diseases, as studies indicate, have a positive relationship with IAP and related health outcomes. Besides this, using odds ratios (OR) and healthcare expenditure data (per capita),

Indoor Air Pollution and Concerned Health Costs in Indian Context

the relative economic burden on women has been arrived at. Data has been sourced from the Ministry of Health, Government of India and other internationally recognised agencies. Given the limited scope of our study, a descriptive analysis of IAP due to fuel-use using secondary data has been undertaken, while deriving on observations from literature. Section 2 of the paper elaborates on the methodology used, while the findings and discussion are presented in section 3. Section 4 concludes the paper.

(1) Literature Review

A review of literature with regard to the objective under our study initially points out the existence of a vast number of studies, observing the relationship of IAP and household cooking using solid fuels. Such studies pertain mainly to the field of medical sciences but do help us in assessing the quantified effect of pollution on women. In a study of COPD, [3] observed its prevalence among adults in Tamil Nadu to be 22.1% with women facing 12.2% of the illness.

In the context of other nations, [4] observed in a study of French households that IAP cost approximately EUR 20 billion in 2004. [5] in a study of Indonesia, Philippines and Timor-Leste observes health costs to be \$ 1.4 billion (0.4% GNI, 2006), \$ 435 million (0.4% GNI, 2003) and \$ 12.5 million (1.4% GNI, 2006) respectively. Given the small size of these three nations, economic burden due to IAP has been found to be significantly higher. [6] in a study of Mexican households found traditional stoves to be highly inefficient and discovered a correlation between IAP and household expenditure on cooking fuels. In Chinese households using solid fuels, [7] observes a significant negative effect on both health and cognitive outcomes of women and a corresponding rise in treatment costs. Females were found to be more vulnerable to IAP and consistently suffered. For Singapore, [8] had observed the total economic cost of IAP to be \$ 3.6 billion (4.31% of GDP, 1999). The study concluded that given the value of statistical lives and cost of illness incurred, substantial money would have been saved which otherwise could have been used in welfare programmes for people.

In India's context, a World Bank report titled "An Analysis of Physical and Monetary losses of Environmental Health and Natural Resources of India" (2013), estimated the total annual cost of IAP to be ₹ 305-1425 billion with a mean estimate of about ₹ 865 billion or 1.3% of GDP in 2009. COPD was associated with 68% of this cost while 32% was related to acute respiratory illness among children. Apart from this, a review of the literature suggests that there has been no such credible reports or studies which have estimated the cost of IAP, not to mention, the specific economic burden of IAP on women. Therefore, the present study has been undertaken to cover such a research gap.

(2) Conceptual Framework

Indoor air pollution: IAP is defined as the chemical, biological and physical contamination of indoor air (OECD), which can invariably result in adverse consequences on health. Smoke associated with combustion of fossil fuels, biomass or firewood contains particulate matter, carbon content (carbon dioxide, carbon monoxide) and other gaseous substances that can accentuate such health effects and may prove to be life threatening.

COPD and asthma: Chronic obstructive pulmonary disease is referred to as a disease of the lungs that obstructs airflow and interferes with normal breathing. Asthma, on the other hand, is an inflammation of the bronchi, narrowing the pathways

and cause respiratory troubles. Both the diseases are long-term in nature, are common, preventable and treatable. However, their global disease burden is staggering, with greater percentages of deaths in middle and low-income nations. Their main cause is exposure to IAP, as a result of smoke from cooking or tobacco.

(3) Objective

To examine and analyse the impact of indoor air pollution on women vis-à-vis health costs, in the context of India.

(4) Limitation of The Study

The limitations of the study include:

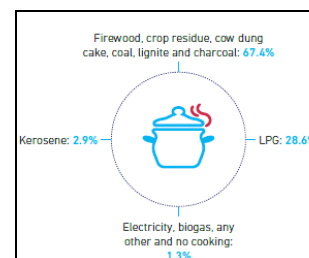
- It is based entirely on secondary data and as such, inconsistencies may exist within the data set.
- The study does not include tobacco which is also a major pollutant.
- The analysis of economic burden is limited to COPD and asthma, whereas a wide range of diseases afflict women exposed to IAP.

II. MATERIALS AND METHODS

Air pollution in terms of outdoor sources are given more preference in policymaking, since these constitute a larger part of total emissions. At the same time, indoor sources of air pollution also require necessary attention due to its immediate impact upon the population. Exposure to population depends upon the amount of time spent within the household. This gathers more significance in regard to women and children, the former being the most exposed due to her nature of household work and position in the society.

(1) Cooking energy mix among Indian households

The NSS 68th round results indicate that only 24.8 women out of every 100 worked in rural areas, while it was 54.3 for men. In urban areas, for every 54.6 working males, only 14.7 were employed women. It can be seen that majority of the women members in a family remained engaged in household activities compared to men. Further, about 83% of rural households and 20% of urban households use solid fuels for cooking (Census 2011). As such, regarding fuels used for cooking in India, fossil fuels and other conventional sources of energy still dominate the energy mix. An IEA report (2016) observed that almost 700 million people depended on solid fuels for cooking, with firewood and kerosene being the most used fuels.



Source: 2011 Census

Figure 1: Fuel mix in household cooking

As figure 1 indicates, dirty fuels contribute to more than 70% of cooking energy, while cleaner fuels contribute to less than 30%, on an average in India. Besides this, the disparity between urban and rural areas is significant.

In urban areas, dependency on dirty fuels is around 40% while LPG usage accounts for 65%. A crucial aspect of such statistics is that access to cleaner fuels is a challenge in slum areas and around 5 million of slum households rely on solid biomass, coal and kerosene for cooking. In rural areas, around 80% use dirty fuels, with coal being used mostly in the central Indian states. Considering the emission factors of these energy sources, the corresponding impact has been analysed in the study.

(2) Exposure to IAP

The incidence of indoor air pollution depends primarily on the type of cooking arrangement in the households, apart from the fuels used. It is widely known that in India, the female population in more than 95% of Indian households are involved in cooking practices and hence, are expectedly more vulnerable to IAP, given the type of stoves or *chulhas* that are used. With regard to our present study, it is important for us to do an analysis of exposure of women to IAP.

(3) Burden of disease

WHO categorises IAP, caused due to dirty fuels, as the 4th leading cause of health risk in developing nations. Globally, IAP caused 35 million deaths and 4.5% global -adjusted DALY in 2010, while accounting for 16% particulate matter pollution. Not surprisingly, IAP in India is considered the second largest killer with more than one million deaths in India annually.

The most significant pollutant that converts dirty fuels into life-threatening substances is the particulate matter and carbon emitted from their combustion. Numerous studies cite that particulate matter (PM₁₀ and PM_{2.5}) have significant positive relationship with morbidity and mortality outcomes. [9] observe that such particulate matter can lead to increased lung cancer mortality. This study presents a discussion on the burden of disease based on literature and related statistics.

(4) Women role in household decision making

It is no secret that India is still on the road to being an egalitarian society wherein women and men have an equal status in household decision making and both have complete control over their earnings and on the decisions regarding to what to do with the money. Official statistics paint a positive picture wherein 61% of married women have stated that they make decisions on household expenditure jointly with their husband, while 21% women make those decisions alone. A mere 17% of households have the husband as the sole decision-maker. This trend has remained more or less same for the last decade. Interestingly, women's control over their earnings increase with their literacy status, and is higher in urban areas, than rural. This is being discussed in the context that women are considered to participate in household decisions "if they make decisions alone or jointly with their husband in three of the following areas: woman's own health care, major household purchases and visits to the woman's family or relatives" [10].

(5) Economic burden of COPD and Asthma:

To estimate the economic burden of COPD on women, data pertaining to cost of treating COPD and asthma, for the period 1991-2016 was considered. These have been obtained from the National Centre of Medical Health (NMCH). In arriving at the per capita costs, only population with 30 years of age

and above was taken into account, for both rural and urban areas. An average conversion factor of USD 1= INR 45 for the period was taken. These costs include both the cost of regular medication and hospitalisation costs. The estimation technique for per capita costs of women pertains to a formula employed by World Bank in the report titled "An Analysis of Physical and Monetary losses of Environmental Health and Natural Resources of India" (2013). Odds ratios from table (5) have been employed for this purpose and results are displayed in the next section.

III. FINDINGS AND DISCUSSION

(1) Prevalence of dirty fuels in household cooking

Firewood and coal form the major part of the energy mix used in cooking, while also bearing high carbon and PM emissions intensiveness. As evidence suggests, combustion of these fuels result in high incidence of IAP, which invariably affects the women members of a household. For the sake of reiteration, the incidence of IAP among women has been found to be higher than men, at around 75% of total population. This data can be further substantiated by identifying the aggregate household expenditure done on such fuels for cooking purposes.

Table 1: State-wise expenditures on fuels that cause IAP (in ₹)

State	Firewood	Biomass	Kerosene	Coal
Assam	368	127	105	163
Bihar	328	168	60	325
Chhattisgarh	344	77	52	123
Gujarat	382	121	115	220
Jharkhand	337	118	92	224
Madhya Pradesh	309	179	66	145
Meghalaya	389	53	73	137
Nagaland	508	49	99	169
Odisha	371	100	70	83
Rajasthan	367	113	59	190
Tripura	421	144	78	130
Uttar Pradesh	276	144	60	102
West Bengal	334	114	45	185
Other States	343	121	72	208

Source: Petroleum Planning and Analysis Cell, Government of India

It is easily noticed that almost all the states have a high dependence on firewood and coal, and a limited dependence on kerosene. Firewood has increased prevalence among most of the states with higher expenditures seen in the north-eastern states of Nagaland (₹ 508), Assam (₹ 368) and Meghalaya (₹ 389), while coal has limited usage in these regions. Coal is spent on highest in Jharkhand (₹ 224) due to the existence of coal mines in the state.

Indoor Air Pollution and Concerned Health Costs in Indian Context

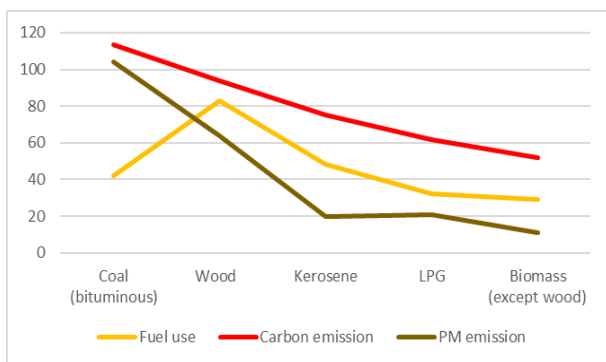
Households in Bihar, Madhya Pradesh, Tripura and West Bengal spend more on biomass compared to coal. If briefly analysed, it is evident that prevalence of dirty fuels is rampant in India, with increased incidence in rural areas, along with slums in urban areas. Interestingly, the impact of this can be better analysed if we tabulate the emission factors of these energy sources.

Table 2: Fuel type and their CO₂ emission factors

Fuel type	Emission factor (kgCO ₂ /MBtu)	Particulate matter emission factors (g/kg)
Coal (bituminous)	113.67	10.4
Wood	93.80	1.6 - 6.4
Kerosene	75.20	2.0
LPG	61.71	2.10
Biomass (except wood)	52.07	10.72

Source: United States Environment Protection Agency (EPA)

Coal and wood have the highest carbon emission factor while particulate matter emission factor is highest for coal and biomass. Kerosene and LPG are one of the cleaner fuels with lower pollution intensiveness. On plotting the usage intensity of these fuels with their emission factors, an expected and correlated trend can be observed.



Source: Author's analysis

Figure 2: Fuel type, usage and their emission factors

Wood with its high pollution intensive nature is the most prevalent of cooking fuel in India. Coal and kerosene trail behind with coal having an equally high IAP intensiveness. These also correlate to high expenditure allocations of households. This invariably indicates the higher incidence of coal and wood related health issues with respect to women, among households that spend more on acquiring such dirty fuels.

(2) High exposure of women to IAP

It is generally understood that the type of cooking apparatus used in households, depends upon the type of fuel used. For instance, in case of LPG, gas stoves are used while kerosene stoves are used for kerosene. Firewood, coal and biomass are associated with traditional *chulhas*. Compared to stoves, *chulhas* tend to be the most inefficient ones wherein incomplete burning of fuels occurs. Moreover, fuels used in *chulhas* are mainly those that are carbon emission intensive in nature and they generally release fifty times more pollutants such as particulate matter, sulphur dioxide and carcinogens [11]. National Family Health Survey (NFHS), 2015-16 states that more than 55% of households are exposed to IAP from

solid fuels and that IAP incidence is critically more when the kitchen is not separately constructed. The following table indicate some relevant data.

Table 3: Housing characteristics vis-à-vis IAP exposure

Housing characteristic	Urban	Rural	Total
Place for cooking in the house			
Separate room	64.3	40.9	49.0
No separate room	26.0	35.9	32.4
Outdoors	3.4	11.2	8.7
In a separate building	5.9	11.6	9.6
Total	100.0	100.0	100.0
Cooking apparatus (solid fuels)			
Stove	3.3	0.8	1.1
Open fire/chulha	96.2	99.1	98.8
Other	0.5	0.0	0.1
Total	100.0	100.0	100.0

Source: NFHS 2015-16

Table 3 categorically indicates that there is a high incidence of cooking inside the house with no separate room, in India, with 35.9% in rural areas while 26% in urban areas. IAP due to this is aggravated by use of open fires or traditional *chulhas* for cooking. However, related secondary statistics is scarce making it necessary for us to do an analysis of primary findings already observed in this context.

In a study of households in Aligarh, Uttar Pradesh, [12] observed total 14 factors that linked women's vulnerability to IAP, which included cooking conditions, cooking related exposures, housing and health conditions. It was observed that women were significantly vulnerable to IAP but the degree of exposure varied with respect to their income levels. Women in the lower income quartile suffered the most as they were using traditional *chulhas*, spent long hours in the kitchen, lived in sub-standard housing, mostly in one-rooms with no ventilation. There was an increased incidence of respiratory infections such as COPD, asthma and pulmonary tuberculosis among them, while issues such as cataract, eye irritations and perinatal mortality was also observed. The study found that the situation of women was aggravated by their inability to receive adequate treatment mostly due to economic backwardness. Pregnant women were found to be the most affected. It should be noted that the study did not cite the economic impact of IAP exposure to women, but does sufficiently imply the economic burden that such households face due to IAP.

A case study of Kolkata conducted by [13] observed that more than 60% households used kerosene predominantly and approximately 60% of such houses were overcrowded and poorly ventilated. As a result, IAP-related diseases affected majority of them with 54% women suffering from critical health problems. Lower age, illiteracy of women and lower per capita income were the main cause of exposures to IAP.

Half of the women respondents had complained of eye irritations while 63% complained of respiratory problems while staying in their houses. Such instances reiterated results of a prominent study by [14] with Bengaluru as the target population. [15], in a case study of 124 households in Kerala, noted that majority used traditional chulhas with an increased incidence of stacking, wherein, women would use open fires for boiling fires and other chores while using LPG stoves to cook food. This technique, although better than the traditional means, also led to sustenance of IAP among lower income households.

(3) High burden of disease

In India’s context, research correlating IAP and health outcomes have been spread across varied fields and sample populations. Nevertheless, aggregating the findings help us underline the key impacts of IAP in the context of diseases. It has been seen that respiratory infections, chronic bronchitis, poor perinatal outcomes (low birth weight and still birth), lung cancer, asthma and COPD are the most common of IAP outcomes. A summary of findings is enumerated below. The subsequent section analyses the disease burden of COPD and asthma, given the purposes of this study.

Table 4: Literature on IAP and its associated health issues

Study	Findings
[16] Mavlankar et al (1991)	50% excess risk of still birth during pregnancy
[17] Mishra et al (2003)	Increased prevalence of asthma among women
[18] Behera et al (2005)	Increased chances of lung cancer in women
[19] Sreeramareddy et al (2011)	Greater chances of low birth weight of babies
[20] Bhat et al (2012)	Positive correlation of solid fuels with acute lower respiratory tract infection
[12] Ashraf et al (2013)	Larger prevalence of conjunctivitis, rhinitis, sore throat, asthma and tuberculosis among women exposed to solid fuels
[3] Saleem et al (2017)	Increased prevalence of COPD among women
[13] Maharana et al (2018)	Larger incidence of eye infection and breathing problems among non-working married women

Chronic obstructive pulmonary disease, although a common, preventable and treatable disease, is estimated to affect more than 15 million people in India, with 9 million males and 6 million females. Globally, it is the 4th leading cause of death while killing almost one million Indians in 2017 [24]. Several meta-analysis studies consistently link COPD with IAP and dirty fuel use [20]. Lower socio-economic status and occupational measures of women have been identified as primary causes of COPD. [21] identifies that women suffer from multiple exposures of particulate matter from common domestic spoke, firewood burning and open stoves, leading to higher incidence of COPD among them (OR: 4.337) compared to males (OR: 4.25), mostly in rural areas. [8, 11, 16,19] had earlier observed similar results with different target populations. The disease burden due to COPD faced by Indian women has been shown below.

Table 5: Number of women patients with COPD (in lakh)

Year	Female		Total patients	
	Urban	Rural	Urban	Rural
1996	11.2	31.6	34.6	95.4
2001	13.2	37.0	39.8	109.6
2006	15.1	42.6	45.3	124.9
2011	17.2	48.3	51.5	141.9
2016	19.7	55.4	59.1	163.0

Source: National Health Profile (NHP), 2016

Similarly, asthma is one of the most widespread non-curable but preventable long-term respiratory diseases in India. Interestingly, India has one in every ten patients of asthma globally with more than 50% of adult cases caused due to particulate matter inhalation (WHO, 2019). In the context of our study, [21] observe that prevalence of asthma is more among poorer households than richer ones, with individuals living an OR of 1.21 due to IAP. The incidence burden was highest among women of poorer households that use solid fuels (firewood ~ 80%, kerosene ~ 78%). Incidence of asthma among Indian women has been tabulated below.

Table 6: Number of women patients with Asthma (in lakh)

Year	Female		Total patients	
	Urban	Rural	Urban	Rural
1996	22.56	83.42	46.73	175.60
2001	24.82	94.76	51.97	195.43
2006	28.30	108.34	59.05	222.68
2011	32.05	122.89	66.62	251.58
2016	35.97	137.99	73.27	277.49

Source: NHP, 2016

For calculating the economic burden of COPD and asthma with respect to IAP, we need to identify their respective odds ratios vis-à-vis women. OR is a proportion of the possibility that a particular event will occur. A meta-analysis of studies observing IAP ORs among Indian households has led to closing down on the values in table 7.

Table 7: Odds ratios for COPD and Asthma for women due to IAP

	Low	High
COPD	2.3*	4.8*
Asthma	1.83**	6.55***

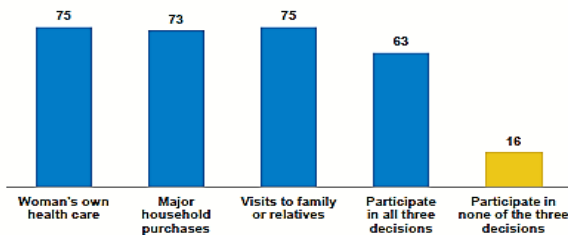
Source: *[14], **[2] ***[15]

(4) Limited role of women in decision making

Pertaining to the discussion in the previous section, in the present study, it has been observed that women have limited in household decision making in case of India. Regarding women’ access to financial resources, evidence suggests that only 42% of women claim to have some money that they can alone decide how to use (NFHS-4), while more than 80% men have control over their money. Besides that, mere 53% of women have a bank or savings account, that they are free to use, while a dismal 41% know properly about credit programmes [22].

Indoor Air Pollution and Concerned Health Costs in Indian Context

This percentage is skewed more towards urban areas and women with better literacy background. Interestingly, data shows that this trend has remained the same just like it was a decade back. Therefore, no significant positive change can be seen whereby it can be concluded that women have a substantial role in household decision-making and expenditure allocation. This is crucial for the objective of our study since greater control of women over her earnings imply positive allocation of money towards shifting to cleaner fuels (LPG) and provision of better healthcare for themselves. [13] observed that more than 50% of women perceived IAP as major health problem but only 20% of them took any measure to reduce it.



Source: NFHS-4

Figure 3: Women's participation in decision making (age 15-49)

(5) Estimating the economic burden of IAP

As regards the methodology outlined in the previous section, the following analysis has been conducted.

Table 9: Economic burden of COPD on women per capita due to IAP (in ₹)

Year	Lower bound			Higher bound		
	Chronic	Acute	Total	Chronic	Acute	Total
1991	19628.9	4541	24169.9	27893.7	6453	34346.7
1996	34857.4	7917.3	42945.7	49534.2	11250.9	61028.1
2001	50427.9	11673.6	62101.5	71660.7	16588.8	88249.5
2006	65827.4	15234.2	81061.6	93544.2	21648.6	115192.8
2011	81226.9	18798.6	100025.5	115427.7	26713.8	142141.5
2016	96626.4	22370.6	118997	137311.2	31789.8	169101

Source: NMCH

The above table indicates the increment in household expenditures for women due to IAP in terms of COPD. This expenditure comes over and above the household expenditure allocations otherwise spent on healthcare. By 2016, expenditure on chronic COPD ranged from a minimum ₹ 96,626 to a maximum of ₹1,37,311. This expenditure coupled with the long-term nature of its treatment, will supposedly create vicious cycle of unnecessary healthcare expenditure which could have been otherwise prevented [23].

The following table denotes the household economic burden of asthma due to IAP.

Table 10: Cost of treating asthma for women per capita per year (in ₹)

Year	Urban	Rural
1996	9,944	9,089
2001	13,064	12,868
2006	16,996	16,741
2011	20,887	20,572
2016	24,277	23,966

Table 8: Cost of treating COPD women per capita per year (in ₹)

Year	Chronic COPD	Acute COPD	Total treatment cost
1991	10,331	2,390	12,721
1996	18,346	4,167	22,603
2001	26,541	6,144	32,685
2006	34,646	8,018	42,664
2011	42,751	9,894	52,645
2016	50,856	11,774	62,630

Source: NMCH

Table 8 indicates that COPD treatment cost has been exponentially increasing since 1991 to a staggering ₹ 50, 856 in 2016, for chronic COPD. This being the most common and widespread COPD incidence, such a treatment cost will expectedly hit low income households heavily. The economic burden COPD incidence on women due to IAP, using ORs and annual expenditure data, has been estimated and enumerated in table 9.

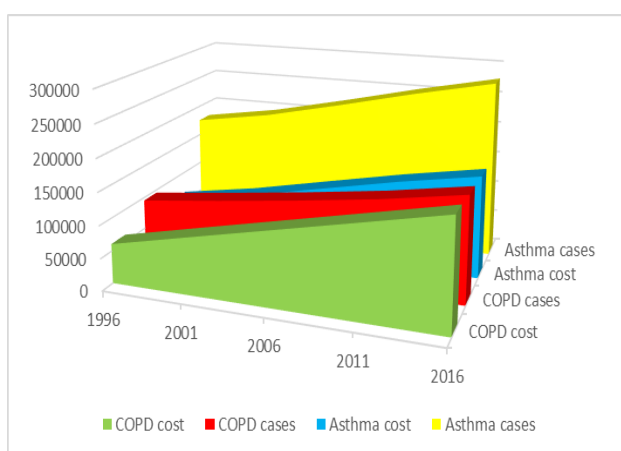
The economic burden of asthma on women due to IAP has been estimated and enumerated in table 11, based on ORs and annual expenditures.

Table 11: Economic burden of Asthma on women per capita due to IAP (in ₹)

Year	Lower bound		Higher bound	
	Urban	Rural	Urban	Rural
1996	18197.52	16632.87	65133.2	59532.95
2001	23907.12	23548.44	85569.2	84285.4
2006	31102.68	30636.03	111323.8	109653.6

2011	38223.21	37646.76	136809.9	134746.6
2016	44426.91	43857.78	159014.4	156977.3

Treating asthma is cheaper than COPD due to its common nature and simpler techniques of treatment. However, household expenditure allocation is seen to be substantially crucial when it comes to poorer households. In 2016, women had to spend minimum ₹ 44,426 in urban areas and ₹ 43,857 in rural areas for treating their asthma, and a maximum of ₹ 1,59,014 and ₹ 1,56,977 respectively [24]. This represents a significant loss of opportunity cost for women wherein such amount could have been spent on other household welfare activities or switching to better cooking fuels or apparatus [25]. LPG fuels costs way less than such healthcare allocations, and on usage, could have prevented recurrence of such diseases.



Source: Author's analysis

Figure 4: Cost of COPD and asthma treatment due to IAP for women vis-à-vis disease burden

IV. CONCLUSION

As part of the present study, the estimated household expenditure allocation or economic burden on women due to IAP is a minimum ₹ 96,626 to a maximum of ₹1,37,311 for COPD per capita per year. For treating asthma, women had to spend minimum ₹ 44,426 in urban areas and ₹ 43,857 in rural areas and a maximum of ₹ 1,59,014 and ₹ 1,56,977 respectively. This invariably substantiates the need for increase expenditure on IAP related health outcomes for vulnerable households. The world today is choking amidst an alarming rise of pollution in all kinds and forms. International consensus has been achieved regarding it and India too has led pioneering efforts in combating pollution. Indoor air pollution, being one of the most dangerous forms of pollution prevalent widely in developing nations, needs widespread technological and governmental policymaking as well as sustained community efforts to be reduced and prevented. As part of this study, it has been observed that IAP expectedly results in adverse health outcomes for vulnerable sections such as women, and puts an excess burden on them in terms of expenditure allocations towards healthcare. Such economic burden has to be reversed and gradually eliminated if India, as a rising superpower, has to move on a path of sustainable development while reaping its demographic dividend. Human

capital will be forming a crucial pillar of productivity in this journey, especially its women.

REFERENCES

- D.G. Fullerton, B. Nigel and Stephen, Indoor Air Pollution from Biomass Fuel Smoke Is a Major Health Concern in the Developing World, *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 2008, 102 (9): 843–51.
- A. Kankaria, et al. Indoor Air Pollution in India: Implications on Health and its Control, *Indian Journal of Community Medicine*, 2014, 39(4): 203-7.
- M. Saleem, et al., A study on the prevalence of chronic obstructive pulmonary disease among adults in Madurai, Tamil Nadu, *International Journal of Community Medicine and Public Health*, 2017, 4(11):4113-4119.
- G. Boulanger, Socio-economic costs of indoor air pollution: A tentative estimation for some pollutants of health interest in France, *US National Library of Medicine*, 2017.
- A. Arcenas, et al., The Economic Costs of Indoor Air Pollution: New Results for Indonesia, the Philippines, and Timor-Leste. *Journal of Natural Resources Policy Research*, 2010, 2(1): 75-93.
- P. Maldonado, et al., Indoor Air Pollution in Mexico, *The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources*, Mexico, 2011.
- Y. Qiu, et al., The impact of indoor air pollution on health outcomes and cognitive abilities: Empirical evidence from China, Jinan University Press: China, 2013.
- E. Quah, et al., The economic cost of particulate air pollution on health in Singapore, *Journal of Asian Economics*, 2003, 14(1): 73-90.
- Disaster Management and Climate Change Unit, Sustainable Development Department, South Asia Region, India: Diagnostic Assessment of Select Environmental Challenges, World Bank Working Paper, 2013.
- International Institute for Population Sciences (IIPS) and ICF, *National Family Health Survey (NFHS-4)*, 2015-16: India. Mumbai: IIPS
- K. Smith, National burden of disease in India from indoor air pollution, *PNAS*, 2000, 97(24): 13286-13293
- Ashraf, S. et al (2013) "Effects of indoor air pollution on human health: A micro-level study of Aligarh City-India" *Merit Research Journal of Education and Review*, 1(6):139-146.
- S. Maharana, et al., Exposure to indoor air pollution and its perceived impact on health of women and their children, *Indian Journal of Public Health*, 2018, 62: 182-187.
- P. Kumar and U. Ram, Patterns, factors associated and morbidity burden of asthma in India" *PLoS One*, 2017, 12(10): e0185938
- S. Agrawal, et al., Occupations with an increased prevalence of self-reported asthma in Indian adults, *The Journal of Asthma*, 2014, 51(8): 814-824.
- D. Mavlinkar, C. Trivedi and R. Gray, Levels and risk factors for perinatal mortality in Ahmedabad, India, *World Health Organ*, 1991, 69: 435-442.
- V. Mishra, Effect of indoor air pollution from biomass combustion on prevalence of asthma in the elderly, *Environment Health Perspective*, 2003, 111:71-8.
- D. Behera, S. Dash and S.K Malik, Blood carboxyhaemoglobin levels following acute exposure to smoke of biomass fuels, *Indian Journal of Medical Research*, 1998, 88:522-4.
- CT Sreeramareddy, Association between biomass fuel use and maternal report of child size at birth — an analysis of 2005-06 India Demographic Health Survey data, *BMC Public Health*, 2011, 11:403.
- O. Kurmi, et al., COPD and chronic bronchitis risk of indoor air pollution from solid fuel: a systematic review and meta-analysis, *Thorax*, 2010, 65(3).
- H. Kumar, Study of association between exposure to indoor air pollution and chronic obstructive pulmonary disease among nonsmokers in a North Indian population – A case-control study, *Indian Journal of Respiratory Care*, Delhi, 2019.
- A. Jain, et al, Access to Clean Cooking Energy and Electricity: Survey of States, *Council on Energy, Environment and Water (CEEW)*: Delhi, 2018.

Indoor Air Pollution and Concerned Health Costs in Indian Context

23. W. Viscusi, *Pricing Lives: Guideposts for a Safer Society*, Princeton University press: New Jersey, 2017.
24. Institute for Health Metrics and Evaluation, *Global Burden of Disease*, 2017.
25. A. Majumder, and S. Madheswaran, Value of Statistical Life in India: A Hedonic Wage Approach, Discussion paper for *Institute for Social and Economic Change*, 2018

AUTHORS PROFILE



Arup Kumar Hazarika Professor, Department of Zoology, Cotton University, Assam, India. Dr. Hazarika is a member of British Ecological Society (elected), Ecological Society of America, Commission on Ecosystem Management (IUCN), International Society of Zoological Sciences, International Association for Ecology (INTECOL) and The World Affairs Council. He has also attended numerous national and international conferences as presenter/key-note speaker/ invitee including conferences held in the University of Colombia (2004), University of San Jose (2006), University of Port Elizabeth (2007), Chinese Academy in Beijing (2009), University of Alberta in Canada (2010), Baltimore (2013), France (2015) and lately, in the National University of Singapore (2016).



Unmilan Kalita Research Scholar, Department of Economics, Gauhati University, Assam, India. Mr. Kalita has completed his B.Sc. (hons.) in Economics from the prestigious Cotton College and M.Sc. (Economics) with specialization in Econometrics, Environmental Economics, Financial Economics and Operations Research from the University of Gauhati and is pursuing M.Phil. (Economics) in the latter. He has also presented papers in international and national seminars along with publishing a number of research papers in renowned national and international journals.